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ΔΙΔΑΚΤΟΡΙΚΗ ΔΙΑΤΡΙΒΗ

ΠΕΡΙΟΡΙΣΜΟΙ ΣΤΟ ΧΡΟΝΟ ΕΠΙΣΚΕΨΗΣ ΧΩΡΩΝ ΠΟΛΙΤΙΣΜΟΥ: ΜΙΑ ΠΡΟΣΕΓΓΙΣΗ ΑΠΟ MINI ΣΕ NANO-ΠΑΙΧΝΙΔΙΑ

CULTURAL SITES VISIT TIME CONSTRAINTS: AN APPROACH FROM MINI TO NANO GAMES

ΕΥΓΕΝΙΑ ΡΟΜΠΑ

ΤΡΙΠΟΛΗ, 2022

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Abstract

Museums, Institutes and Organizations (MIOs) strive to ensure that every visitor leaves their venues with an understanding of one or more basic messages, a notion that they wish to communicate. However, providing a high Quality of Experience (QoE) to MIO visitors, while exploiting every second of a visitor's visit time is demanding and challenging.

In an effort to improve visitors' QoE while keeping their visiting time within their expectations, we propose a new holistic approach based on three consecutive visit phases being: (a) "*before the visit*", (b) "*actual visit*" and (c) "*after the visit*". Our framework provides suggestions for creating content for MIOs while keeping visitors engagement time to minimum. For each phase of the MIO visit we provide suggestions on (a) the visit preparation when visitor profiling can be acquired in an effort to minimise visit time and maximize QoE, (b) the actual visit and ways of communicating aright the MIOs basic message(s) in a matter of seconds, and (c) keeping the interest after one's visit and engage more visitors. Depending on visitors' requirements we propose *visit elongation* and/or *message passing* as approaches in different phases of one's visit. Visit elongation exploits visitor's time before or/and after their visit with personalization tools and sharing means. Message passing is preferred when visitor's time is limited and/or visitors are unaware of the available visit elongation tools. Message passing exploits nano-games, a novel concept introduced for the sake of this thesis, which are *short, easy to master, self–contained games of a single level of difficulty, able to mastered within a matter of seconds.*

Evaluation has showed promising results, with MIOs providing a qualitative informational experience to their visitors. Regardless of shortness in time or of the crowds that may exist, especially in peak hours, visitors are able to get the maximum experience possible adjusted for their needs.

Dedicated to my family,

for their unconditional love,

support and encouragement.

Acknowledgements

There are many individuals who contributed to the production of this thesis through their moral support, advice or participation. I would like to express my most sincere gratitude to them all.

First of all, I would first like to thank my supervisor, Professor George Lepouras, whose contribution was invaluable. Thank you for your guidance, patience, careful supervision and encouragement throughout the years.

I would also like to thank Dr. Rold Landua for the once-in-a-lifetime opportunity to become part of CERN MediaLab team as a PhD Intern. It has been both a privilege and a pleasure to have experienced the opportunity to be part of a team of such extraordinary people. I would particularly like to also thank João Pequenão for being supportive, enthusiastic and inspiring throughout my internship at CERN MediaLab.

I am pleased to say thank you to Dr. Angela Antoniou for kindly assisting me with the statistical analysis in this dissertation and being patient with my knowledge gaps in the area.

I would like to also thank the Microcosm museum for hosting my nano-game, HEAL, in their exhibition as well as the evaluation participants that spent a significant amount of time entering their personal information on the questionnaire.

Lastly, I would like to thank my family for their understanding, encouragement and support. They have always been the greatest support through the whole process, encouraging me to keep going when frustration and other problems drained my motivation. Their support, love, help and encouragement cannot be thanked enough.

Evgenia Rompa

Related Publications

J. Rompa, G. Lepouras, A. Antoniou, and J. Pequenão, "Nano-Games for Cultural Venues: the HEAL game", *International Journal of Serious Games,* vol. 7, pp. 3-25, 2020, doi: 10.17083/ijsg.v7i2.344.

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Περίληψη

Τα μουσεία έχουν ως βασικό έργο τους τη συλλογή, μελέτη, διατήρηση, και έκθεση αντικειμένων. Τα τελευταία χρόνια ωστόσο έχουν εξελιχθεί σε εκπαιδευτικά, καινοτόμα ινστιτούτα, καλύπτοντας τις ανάγκες και τα ενδιαφέροντα διαφορετικών ανθρώπων [1]. Συχνά, οι επισκέπτες ενός μουσείου είναι ετερογενείς ομάδες, όπως για παράδειγμα οργανωμένες επισκέψεις, μαθητές, οικογένειες, κλπ., γεγονός που συνεπάγεται διαφορετικά κίνητρα και ανάγκες επίσκεψης [2, 3]. Μελέτες [4-6] έχουν δείξει πως οι επισκέπτες ενός μουσείου αναμένουν μια διασκεδαστική εμπειρία, ανεξάρτητα από το κίνητρο της επίσκεψής τους. Κατά συνέπεια, τα μουσεία υιοθετούν όλο και περισσότερο τις ψηφιακές τεχνολογίες [7-11] έτσι ώστε να προσφέρουν διασκεδαστικούς τρόπους εκμάθησης καλύπτοντας παράλληλα τις ανάγκες και τα ενδιαφέροντα των επισκεπτών [12, 13].

Εκτός από τα μουσεία, υπάρχει και πλήθος άλλων οργανισμών και ινστιτούτων που φιλοξενούν δικές τους εκθέσεις σε δικούς τους χώρους. Πανεπιστήμια, αθλητικοί χώροι, ακόμη και μνημεία (όπως για παράδειγμα ο Πύργος του Άιφελ), διαθέτουν εκθέσεις προκειμένου οι επισκέπτες τους να μάθουν περισσότερα για την ιστορία τους καθώς και τη συμβολή τους στην κοινωνία μας.

Παρόλο που τα Μουσεία, τα Ινστιτούτα και οι Οργανισμοί (ΜΙΟ) προσπαθούν να διασφαλίσουν ότι κάθε επισκέπτης έχει αντιληφθεί και κατανοήσει το βασικό μήνυμα της έκθεσης μετά την επίσκεψή του, υπάρχουν συχνά περιπτώσεις όπου αυτό δε συμβαίνει [14]. Αυτό οφείλεται στο ότι τα ΜΙΟ παρέχουν πληθώρα πληροφορίας, ανεξάρτητα της βαρύτητας και της σημασίας της, με αποτέλεσμα οι επισκέπτες να αφιερώνουν χρόνο σε εκθέματα που δεν τους ενδιαφέρουν. Τέτοιες περιπτώσεις είναι

πιο συχνές όταν οι επισκέπτες κινούνται ελεύθερα στο χώρο της έκθεσης, χωρίς κάποια κατεύθυνση ή καθοδήγηση ή σε ομαδικές επισκέψεις όπου ακολουθούν την πορεία της μάζας. Τελικώς, η έλλειψη χρόνου αλλά και η αναπόφευκτη κούραση επηρεάζουν την ποιότητα εμπειρίας με αποτέλεσμα οι επισκέπτες να μην είναι πρόθυμοι να επισκεφθούν ξανά την έκθεση ή να την προτείνουν σε άλλους.

Σε μια προσπάθεια εξάλειψης αυτού του φαινομένου, τα ΜΙΟ έχουν υιοθετήσει μια προσέγγιση που επικεντρώνεται στον επισκέπτη, με στόχο να προσφέρουν καλύτερη εμπειρία επίσκεψης. Οι εκθέσεις εμπλουτίζονται με πιο ελκυστικό και διασκεδαστικό περιεχόμενο προκειμένου να κεντρίσουν το ενδιαφέρον των επισκεπτών τους, αλλά και να προσφέρουν μια εμπειρία υψηλής ποιότητας και γρήγορης μάθησης, ανεξάρτητα από το υπόβαθρο και την ηλικία του κοινού τους. Ένας επισκέπτης μπορεί να θεωρηθεί πώς αποκόμισε γνώση αν μπορεί να αναγνωρίσει γενική ιδέα που “κρύβει” ένα έκθεμα με το οποίο έχει αλληλεπιδράσει [15]. Τα τελευταία χρόνια τα πληροφοριακά παιχνίδια έχουν αποδειχθεί ως προτιμώμενο μέσο μαθησιακού περιβάλλοντος έχοντας ως επίκεντρο τον επισκέπτη [16, 17]. Ολοένα και περισσότεροι πολιτιστικοί χώροι [18-20] προσθέτουν παιχνίδια στις εκθέσεις τους σε μία προσπάθεια βελτίωσης της εμπειρίας και της εκμάθησης επισκεπτών. Παρόλο που τα παιχνίδια φαίνεται να είναι μια υποσχόμενη προσέγγιση σε μία διαρκή πρόκληση, υπάρχουν περιορισμοί που θα πρέπει να ληφθούν υπ’ όψιν. Τέτοιο παράδειγμα είναι η εκμάθηση του παιχνιδιού, για την οποία ένας επισκέπτης πρέπει να αφιερώσει χρόνο. Μελέτες έχουν δείξει πως οι επισκέπτες ενός ΜΙΟ δεν αφιερώνουν περισσότερο από 90 λεπτά από το χρόνο τους στην έκθεση, ανεξάρτητα από το θέμα ή το μέγεθός της [12, 21-26]. Ο χρονικός περιορισμός γίνεται πιο απαιτητικός όσον αφορά τα εκθέματα, αφού οι επισκέπτες αφιερώνουν περίπου 2 λεπτά σε κάποιο έκθεμα [27, 28]. Προκειμένου οι επισκέπτες να μπορούν να αντιληφθούν το βασικό μήνυμα μίας έκθεσης ή ενός εκθέματος σε τόσο σύντομο χρονικό διάστημα, θα πρέπει να υιοθετηθεί μία νέα προσέγγιση.

Η νέα προσέγγιση θα πρέπει να εστιάσει στις παρακάτω τρεις προκλήσεις:

- Οι επισκέπτες αφιερώνουν περιορισμένο χρόνο σε μια έκθεση [12, 21-26] και μόνο μερικά λεπτά ανά έκθεμα [27, 28].
- Οι επισκέπτες συχνά αποτυγχάνουν να κατανοήσουν πλήρως το μήνυμα της έκθεσης και μερικές φορές φεύγουν με μια παρερμηνευμένη ή λανθασμένη ιδέα [14].
- Συχνά η Ποιότητα της Εμπειρίας Επισκέψεων (QoE) δεν είναι η βέλτιστη,

Η αντιμετώπιση αυτών των προκλήσεων είναι ζωτικής σημασίας για την ικανοποίηση των επισκεπτών. Η απόκτηση νέας γνώσης είναι υψηλής προτεραιότητας, ειδικά για επισκέψεις με εκπαιδευτικό σκοπό [29]. Αν οι επισκέπτες δεν λάβουν το μήνυμα των ΜΙΟ, το κίνητρό τους δεν εκπληρώνεται. Αυτό προκύπτει συχνότερα σε περιπτώσεις όπου οι επισκέπτες συμμετέχουν σε μια ομαδική επίσκεψη (π.χ. σχολικές ομάδες) όπου πρέπει να «πάνε με τη ροή» και να ακολουθήσουν ένα προσυμφωνημένο πρόγραμμα. Μια προσέγγιση που εκμεταλλεύεται καλύτερα τον χρόνο επίσκεψης, ενώ βοηθά τους επισκέπτες να μάθουν κάτι νέο, προσφέροντας παράλληλα μια βελτιωμένη εμπειρία επίσκεψης, είναι ουσιαστικής σημασίας.

Η χρήση έξυπνων προτάσεων που καθοδηγούν τους επισκέπτες προς εκθέματα του ενδιαφέροντός τους μπορεί να βελτιώσει την εμπειρία της επίσκεψής τους, διατηρώντας παράλληλα τον χρόνο επίσκεψης εντός των προσδοκιών τους. Οι εξατομικευμένες εφαρμογές μπορούν να παρέχουν αποτελεσματικές λύσεις φιλτραρίσματος ή καθοδήγησης έτσι ώστε να βοηθήσουν τους επισκέπτες να βρουν και να εστιάσουν σε εκθέματα της αρεσκείας τους. Με αυτόν τον τρόπο, η επίσκεψη σε ένα ΜΙΟ μετατρέπεται σε προσωπική εμπειρία, προσαρμοσμένη στα ενδιαφέροντα, τα προφίλ ή/και τις προσδοκίες κάθε επισκέπτη. Ωστόσο, η συγκέντρωση προτιμήσεων των επισκεπτών πρέπει να γίνει έγκυρα και σε σύντομο χρονικό διάστημα δεδομένου πως ο χρόνος επίσκεψης είναι περιοριστικός. Η αξιοποίηση του χρόνου πριν και/ή μετά

την επίσκεψη μπορεί να παρατείνει την συνολική διάρκεια επίσκεψης, είτε ενώ ο επισκέπτης προετοιμάζει την επίσκεψή του, είτε μετά ενώ μοιράζεται την εμπειρία του με άλλα άτομα [30-35]. Ωστόσο, η εν λόγω προσέγγιση δεν είναι πάντα εφικτή αφού πολλές φορές οι επισκέπτες δε γνωρίζουν την ύπαρξη εργαλείων εξατομίκευσης πριν την επίσκεψή τους, ή δεν έχουν τους πόρους ή τις δεξιότητες για να τα χρησιμοποιήσουν.

Για το σκοπό αυτό, προτείνουμε μια νέα ολιστική προσέγγιση. Η προσέγγιση βασίζεται στις τρεις διαδοχικές φάσεις μίας επίσκεψης σε ΜΙΟ, που είναι: (α) «πριν από την επίσκεψη», (β) «πραγματική επίσκεψη» και (γ) «μετά την επίσκεψη». Διάφορες εφαρμογές μπορούν να χρησιμοποιηθούν σε οποιαδήποτε από αυτές τις φάσεις, προκειμένου να ενισχυθεί η εμπειρία των επισκεπτών. Κάθε επιλογή προσφέρει διαφορετικά πλεονεκτήματα και μπορεί να χρησιμοποιηθεί σε διαφορετικές περιπτώσεις, ωστόσο μοιράζονται τον ίδιο στόχο, αυτόν της βελτίωσης της εμπειρίας του επισκέπτη. Προτείνουμε επίσης τους ακόλουθους βασικούς πυλώνες για καθεμία από τις προαναφερθείσες φάσεις:

- **Η προετοιμασία είναι σημαντική αλλά όχι απαραίτητη (Φάση Α)**: Το προφίλ ενός επισκέπτη μπορεί να σχηματιστεί πριν από την επίσκεψη. Οι πιο κοινοί τρόποι διαμόρφωσης προφίλ χρηστών είναι τα ερωτηματολόγια και η παρατήρηση. Ωστόσο, οι επισκέπτες δεν είναι πάντα πρόθυμοι να αφιερώσουν τον χρόνο ή να παρέχουν τις απαραίτητες πληροφορίες όταν επισκέπτονται ένα ΜΙΟ. Από την άλλη, στην παρατήρηση χρειάζεται να συλλεχθούν αρκετά δεδομένα προκειμένου να διαμορφωθεί ένα προφίλ χρήστη. Πιστεύουμε ότι η διαμόρφωση του γνωστικού προφίλ, η συγκέντρωση ενδιαφερόντων και η σύνθεση του προφίλ επίσκεψης του χρήστη θα πρέπει να γίνονται με διασκεδαστικό και ελκυστικό τρόπο. Επιπλέον, προτείνουμε την παροχή εργαλείων εξαγωγής προσωποποιημένων προφίλ στους πιθανούς επισκέπτες

πριν από την επίσκεψή τους. Αποκτώντας το προφίλ χρήστη πριν την επίσκεψη και προτείνοντας εξατομικευμένο περιεχόμενο, οι επισκέπτες θα περνούν το χρόνο τους στο ΜΙΟ περιηγούμενοι στα εκθέματα που τους ενδιαφέρουν, ελαχιστοποιώντας το χρόνο τους μπροστά σε εκείνα που δεν βρίσκουν ελκυστικά. Ωστόσο, όταν δεν είναι εφικτό να διαμορφωθεί το εξατομικευμένο προφίλ ενός επισκέπτη (πχ. λόγω χρόνου, πόρων, δεξιοτήτων), δεν θα πρέπει να επηρεάζεται η εμπειρία των επισκεπτών.

- **Η επίσκεψη είναι ζωτικής σημασίας (Φάση Β)**: Κάθε δευτερόλεπτο του χρόνου των επισκεπτών έχει σημασία και πρέπει να αξιοποιείται στο βέλτιστο. Οι επισκέπτες θα πρέπει να μπορούν να βρίσκουν ενδιαφέρον και ελκυστικό περιεχόμενο που θα βοηθήσει στην κατανόηση του(των) μηνύματος(ων) του ΜΙΟ στον περιορισμένο χρόνο της επίσκεψής τους. Ακόμη και σε περιπτώσεις όπου η εξατομίκευση περιεχομένου δεν είναι εφικτή ή πρακτική και ο χρόνος επίσκεψης είναι περιορισμένος, τα ΜΙΟ θα πρέπει να είναι σε θέση να επικοινωνούν ένα βασικό μήνυμα στους επισκέπτες τους.
- **Διατήρηση του ενδιαφέροντος (Φάση Γ)**: Τα ΜΙΟ θα πρέπει να διατηρούν το ενδιαφέρον των επισκεπτών τους ακόμα και μετά την επίσκεψή τους. Με αυτόν τον τρόπο, οι επισκέπτες θα είναι πρόθυμοι να επισκεφθούν ξανά και/ή να προτείνουν την εμπειρία τους σε άλλους. Η πρόταση/προτροπή προς επίσκεψη μπορεί να γίνει μέσω ευρέως διαδεδομένων μεθόδων και πλατφορμών, όπως για παράδειγμα με τη χρήση των Social Media.

Ανάλογα με τις απαιτήσεις του κάθε επισκέπτη, προτείνουμε δύο εναλλακτικές, καθεμία από τις οποίες εφαρμόζεται σε διαφορετικές φάσεις της επίσκεψης:

Α. **Επιμήκυνση επίσκεψης**, η οποία ισχύει κατά τις Φάσεις Α και Γ. Σε αυτήν την περίπτωση, τα ΜΙΟ αξιοποιούν το χρόνο των επισκεπτών τους πριν ή/και μετά την επίσκεψή τους. Αυτό συμβαίνει όταν οι επισκέπτες γνωρίζουν και

χρησιμοποιούν τα διαθέσιμα εργαλεία εξατομίκευσης πριν από την επίσκεψή τους ή/και μοιράζονται την εμπειρία τους με οποιοδήποτε μέσο (π.χ. μέσα κοινωνικής δικτύωσης) μετά την επίσκεψή τους. Η προσέγγιση αυτή παρουσιάζεται στο Κεφάλαιο 2.

Β. **Διαβίβαση μηνύματος**, η οποία ισχύει κατά τη φάση Β. Αυτή η προσέγγιση εφαρμόζεται σε περιπτώσεις όπου οι επισκέπτες έχουν περιορισμένο διαθέσιμο χρόνο. Αυτό ισχύει σε περιπτώσεις όπου δεν έχουν αρκετό διαθέσιμο χρόνο κατά τη διάρκεια της επίσκεψης στο ΜΙΟ ή είναι μέρος μιας ομαδικής επίσκεψης όπου εξαρτώνται κυρίως από το πρόγραμμα της ομάδας. Ομοίως ισχύει και για την περίπτωση όπου οι επισκέπτες ενδέχεται να μην γνωρίζουν ή να μην έχουν το χρόνο ή τις δεξιότητες να χρησιμοποιήσουν τα διαθέσιμα εργαλεία εξατομίκευσης πριν και/ή μετά την επίσκεψή τους. Σε τέτοιες περιπτώσεις, προτείνουμε απλές αλλά ενημερωτικές εφαρμογές και εργαλεία που θα χρησιμοποιηθούν κατά τη διάρκεια της επίσκεψης, προκειμένου να βελτιωθεί την εμπειρία επίσκεψης του ΜΙΟ. Η προσέγγιση αυτή παρουσιάζεται αναλυτικά στο Κεφάλαιο 3.

Αν και οι παραπάνω εναλλακτικές επίσκεψης μπορούν να χρησιμοποιηθούν ανεξάρτητα, ο συνδυασμός και των δύο μπορεί να μεγιστοποιήσει την ποιότητα εμπειρίας ενός επισκέπτη.

Για τις ανάγκες της διατριβής αυτής, αναπτύξαμε δύο εφαρμογές, κάθε μία από τις οποίες ακολουθεί διαφορετική εναλλακτική. Η πρώτη ονομάστηκε «My Museum Experience», η οποία ακολουθεί τις προδιαγραφές της *Επιμήκυνσης Επίσκεψης*, ενώ η δεύτερη ονομάστηκε «HEAL» και έχει ως κύριο στόχο τη *Διαβίβαση μηνύματος* ενός ΜΙΟ.

Το «My Museum Experience» αποτελείται από τρία στοιχεία:

- Ένα παιχνίδι μέσων κοινωνικής δικτύωσης που χρησιμοποιείται ως πηγή πληροφοριών προφίλ (γνωστικά προφίλ, ενδιαφέροντα ΜΙΟ και στυλ επισκέψεων) και ως τρόπος προσέλκυσης επισκεπτών.
- Μία εφαρμογή για κινητά που λειτουργεί ως εξατομικευμένος οδηγός κατά τη διάρκεια επίσκεψης στο ΜΙΟ.
- Έναν αλγόριθμο υπολογισμού προτάσεων και εξατομικευμένης περιγραφής εκθεμάτων για κάθε χρήστη.

Η εξατομίκευση της επίσκεψης ξεκινά πριν την πραγματική επίσκεψη στο ΜΙΟ, με τη χρήση του παιχνιδιού μέσων κοινωνικής δικτύωσης. Το «My Museum Story» (MMS) είναι ένα παιχνίδι στο Facebook στο οποίο οι χρήστες μπορούν να δημιουργήσουν τη δική τους εξατομικευμένη έκθεση σε ένα μουσείο. Για την απόκτηση εκθεμάτων οι χρήστες καλούνται να κερδίσουν κάποιο από τα διαθέσιμα μίνι παιχνίδια. Πριν ξεκινήσουν να παίζουν, οι παίκτες πρέπει να διαλέξουν τον χαρακτήρα τους (avatar) στο παιχνίδι καθώς και τα διάφορα αντικείμενα/εργαλεία που θέλουν έχουν διαθέσιμα. Κάθε χαρακτήρας και αντικείμενο/εργαλείο που διαλέγει ένας χρήστης αντιστοιχεί σε διαφορετικό γνωστικό προφίλ, παρέχοντας έτσι προσωποποιημένη πληροφορία για τον κάθε χρήστη. Μετά την επιλογή του χαρακτήρα και των αντικειμένων/εργαλείων, ο χρήστης βρίσκεται σε ένα άδειο ψηφιακό μουσειακό χώρο όπου καλείται να επιλέξει τη διαρρύθμισή του. Η επιλογή του αυτή υποδεικνύει το στυλ επίσκεψής του [36].

Για τη συλλογή εκθεμάτων, ο χρήστης πρέπει να ολοκληρώσει με επιτυχία κάποιο από τα διαθέσιμα μίνι παιχνίδια [37] και να διαλέξει κάποιο από τις επιλογές που του δίνονται. Τα εκθέματα που προτείνονται είναι από διαφορετικές θεματικές ενότητες έτσι ώστε ο χρήστης να διαλέξει αυτό που επιθυμεί. Η επιλογή αυτή υποδεικνύει τα προσωπικά ενδιαφέροντα ενός χρήστη και καταγράφεται έτσι ώστε να χρησιμοποιηθεί αργότερα κατά τη διάρκεια της πραγματικής επίσκεψης στο ΜΙΟ για τον υπολογισμό των ενδιαφερόντων του χρήστη.

Έχοντας διαθέσιμα το γνωστικό προφίλ, το στυλ επίσκεψης και τα ενδιαφέροντα του χρήστη, ο αλγόριθμος υπολογισμού προτάσεων και περιγραφής εκθεμάτων δημιουργεί μία εξατομικευμένη επίσκεψη για κάθε επισκέπτη προτείνοντας μία αλληλουχία Σημείων Ενδιαφέροντος (POI).

Για την παρουσίαση των προτάσεων αυτών στους επισκέπτες, αναπτύχθηκε μια εφαρμογή για κινητά, το «My Museum Guide» (MMG). Το MMG προσφέρει στους επισκέπτες προτάσεις δρομολόγησης, εξατομικευμένες περιγραφές και προτάσεις εκθέσεων με βάση το προσωπικό προφίλ που έχει υπολογιστεί. Οι χρήστες μπορούν να συνδεθούν στον λογαριασμό τους στο Facebook, και να κοινοποιήσουν την δική τους προσωπική επίσκεψη στους φίλους τους. Κατ΄αυτόν τον τρόπο επεκτείνεται η πραγματική τους επίσκεψη ενώ προσελκύονται νέοι επισκέπτες στο MIO.

Σε περιπτώσεις όπου η *Επιμήκυνση Επίσκεψης* δεν είναι δυνατή ή χρήζει ενίσχυσης, μπορεί να ακολουθηθεί η προσέγγιση *Διαβίβασης Μηνύματος*. Για τις ανάγκες της προσέγγισης αυτής εισαγάγαμε ένα νέο όρο, τα νανο-παιχνίδια. Ένα νάνο-παιχνίδι ορίζεται ως:

> «*ένα σύντομο, εύκολο προς επίτευξη, αυτοτελές παιχνίδι ενός μόνο επιπέδου δυσκολίας. Προκειμένου να διατηρηθεί σύντομο, το νανο-παιχνίδι έχει απλούς και βασικούς κανόνες που παραμένουν αναλλοίωτοι καθ' όλη τη διάρκειά του και προκαλούν τους παίκτες με σαφώς καθορισμένους στόχους, οι οποίοι μπορούν να επιτευχθούν σε λίγα δευτερόλεπτα. Με αυτόν τον τρόπο, επιτρέπουν στους χρήστες τους να εκμεταλλευτούν πλήρως τον χρόνο τους, ειδικά όταν επισκέπτονται μια έκθεση MIO.*»

Τα νάνο-παιχνίδια χρησιμεύουν σε περιπτώσεις όπου το MIO θέλει να μεταφέρει το βασικό του μήνυμα με απλό, διασκεδαστικό τρόπο στους επισκέπτες σε λίγα δευτερόλεπτα, χωρίς να χρειάζεται κάποια εκπαίδευση ή εμπειρία. Το «HEAL» είναι ένα

νάνο-παιχνίδι που αναπτύχθηκε για την αξιολόγηση της *Διαβίβασης Μηνύματος* και έχει ως στόχο να ενημερωθούν οι χρήστες για τη θεραπεία πρωτονίων κατά του καρκίνου. Το σενάριο του HEAL εστιάζει στον τρόπο με τον οποίο λειτουργεί η θεραπεία πρωτονίων, δίνοντας πληροφορίες για τη διαδικασία από το σημείο που ξεκινά η δέσμη πρωτονίων μέχρι το σημείο που η ακτίνα φτάνει στον προορισμό της, μέσα στο ανθρώπινο σώμα. Το νάνο-παιχνίδι είναι ανεπτυγμένο έτσι ώστε ο χρήστης να βρίσκεται μέσα στο περιβάλλον διεπαφής, έχοντας στοιχεία του παιχνιδιού δίπλα του (σε ένα σύνολο από οθόνες) και στο πάτωμα όπου βρίσκεται. Στο HEAL ο χρήστης βρίσκεται μέσα σε ένα ιατρικό εργαστήριο και καλείται να αντιμετωπίσει έναν όγκο (σύνολο καρκινικών κυττάρων) ορίζοντας συγκεκριμένες τιμές σε διάφορα στοιχεία ελέγχου. Οι τιμές που καλείται να επιλέξει προκειμένου να επιτευχθεί ο στόχος του παιχνιδιού γίνονται χρησιμοποιώντας μέρη του σώματός του (χέρια και πόδια). Πιο συγκεκριμένα, ο χρήστης πρέπει να χρησιμοποιήσει τα χέρια του για να στοχεύσει τον όγκο και να ορίσει τη σωστή τιμή ενέργειας έτσι ώστε η θεραπεία έχει επιτυχία. Τελικώς, θα πρέπει να χρησιμοποιήσει τα πόδια του και με μία ώθηση (κλωτσιά) να επιταχύνει τη δέσμη πρωτονίων προς τον στόχο και με την ενέργεια που έχει ορίσει προηγουμένως.

Αν και υπάρχουν διάφορες πηγές εισόδου διαθέσιμες, στα νάνο-παιχνίδια προτείνεται η χρήση αισθητήρων και κοινότοπων χειρονομιών των χρηστών. Κατ' αυτόν τον τρόπο υιοθετείται μία διαισθητική προσέγγιση ελέγχου των στοιχείων του νάνο-παιχνιδιού αφού αξιοποιούνται βιολογικά πρωταρχικές γνώσεις, οι οποίες μειώνουν το γνωστικό φορτίο [38]. Απλές κινήσεις, όπως η υπόδειξη κατεύθυνσης (δείχνω) ή η κλωτσιά, μπορούν να χρησιμοποιηθούν για τον έλεγχο στοιχείων ενός νάνο-παιχνιδιού. Η εν λόγω προσέγγιση ελαχιστοποιεί το χρόνο εκμάθησης του παιχνιδιού, ανεξαρτήτως της ηλικίας ή της εμπειρίας των χρηστών του, δίνοντας τους περισσότερο χρόνο για να απολαύσουν το παιχνίδι.

Οι αξιολογήσεις που έγιναν στα πλαίσια της διατριβής έδειξαν αισιόδοξα αποτελέσματα. Πιστεύουμε ότι η προσέγγιση που προτείνεται συνεισφέρει σημαντικά στην βελτίωση της εμπειρίας επισκεπτών στα ΜΙΟ. Τα εργαλεία εξατομίκευσης προσφέρουν την ευκαιρία προσωποποιημένης επίσκεψης ενώ τα νάνο-παιχνίδια προσφέρουν μια γρήγορη, αλλά ποιοτικά ενημερωτική εμπειρία. Και οι δύο προσεγγίσεις, είναι αποτελεσματικές ανεξαρτήτου του διαθέσιμου χρόνου του επισκέπτη, καθώς στα εργαλεία εξατομίκευσης οι χρήστες βλέπουν τα εκθέματα που πραγματικά θέλουν, ενώ στα νάνο-παιχνίδια αποκομίζουν τη μέγιστη δυνατή διαδραστική εμπειρία μέσα σε λίγα δευτερόλεπτα. Υποστηρίζουμε πως είτε ακολουθηθεί μία εκ των δύο προσεγγίσεων είτε γίνει συνδυασμός και των δύο, τα ΜΙΟ μπορούν να διασφαλίσουν πώς κάθε επισκέπτης θα φεύγει από τον χώρο τους έχοντας κατανοήσει τα βασικά μηνύματα του ιδρύματος.

1 Introduction & Motivation

Museums started with an initial aim to collect, preserve, protect and display objects, specimens and art. Throughout the years museums have evolved into educational, accessible, and innovative institutes serving different people with different needs and interests [1]. Museum visitors form very large and heterogeneous groups, including students, families, individuals, etc. which implies very different visit motivations and needs [2, 3]. With a significant portion of their visitors being scholars, researchers, art connoisseurs and interested tourists, museums' exhibitions should not only focus on research and education but also on publicity and sightseeing, becoming thus centres for education, research, enjoyment and fun. A study conducted by Sheng and Chen [4] has showed that museum visitors highly expect an easy going and fun experience, regardless of their motivation. Moreover, Trotter [5], Kotler et al. [6] claim that museums also function as places for leisure and entertainment.

In order to remain viable, there is a constant need for museums to attract audiences and find ways to understand visitor expectations and experiences, and be responsive to various interests and needs. In this manner, museums aim to provide entertainment, while being at the same time informative and educational. In order to achieve that, museums all the more adopt digital technologies [7] so as to enrich the quality of the physical context in an effort to provide a better experience, while meeting the visitors'

needs and interests. Interactive exhibits [8-11] become more popular, day by day since they simultaneously provide learning, engagement and entertainment [12, 13].

Except for museums, there is a high number of other organisations and institutes hosting their own exhibitions in their venues. Universities, sport venues, even monuments (for example the Eiffel Tower), can create or host exhibitions in order for their visitors to get to know more about the history hidden behind them as well as their contribution to our society.

Even though Museums, Institutes and Organisations (hereafter mentioned as MIOs) make an effort to ensure that every visitor leaves their venues with an understanding of one or more basic messages, a notion that they wish to communicate, often visitors leave without a clue about what the exhibition was about [14]. This is not so much due to a lack of information, as in many cases visitors are provided with an abundance of information, in a MIOs' effort to communicate through their exhibitions as much information as they can, regardless of its significance. This leads to visitors often spending more time on exhibits that do not quite interest them, while missing those that do. This occurs more often in cases where visitors are left to find their way around a MIO's exhibits or even when they are part of a group visit where they have to "go with the flow". Time restrictions or simply the tiredness that inevitably sets-in during visits, can significantly impact visitors' experience. As a result, visitors are not willing to re-visit or recommend their experience to others.

In an effort to eliminate this phenomenon, MIOs have adopted a more visitor-centred approach aiming to offer more of an experience than just a visit. Exhibitions get enriched with more attractive, engaging and even fun content in order to not only captivate their visitors' interest but also provide both a high quality and fast learning experience, regardless of their audience's background and age. Falk and Dierking [15] support that learning can be said to have occurred when a visitor is subsequently able to note the

general idea behind an exhibit that has interacted with. During the last years, generic applications and especially informational games have proved to be a great means of knowledge acquisition and the way to go in achieving this visitor-centred learning environment [16, 17]. As a matter of fact, increasingly more cultural places [18-20] adopt games at their exhibitions in an effort to improve users' experience and enhance the learning outcome. Even though games seem to be a viable solution to a lasting challenge, one may argue that there are numerous constraints that make adopting games in MIOs more difficult than one may think. For example, in order for a user to be able to play a game, one needs to at least understand its gameplay and know how to operate its controls beforehand, meaning that a MIO visitor would need to spend more time than initially estimated for a simple visit. Mastering the game could take even longer as the user would have to be familiar with the gameplay in order to achieve its goal. This gets more challenging as several studies have shown that MIO visitors spend no more than 90 minutes in exhibitions, regardless of their topic or size [12, 21-26], and at most 2 minutes [27, 28] in front of an exhibit. In other words, due to the time constraint, a visitor should understand an exhibit's content and purpose in a matter of seconds. To overcome the time constraint a new approach is essential.

Providing a high Quality of Experience (QoE) to the MIO's visitors, while exploiting every second of a visitor's visit time is demanding. Using intelligent recommendations that route visitors towards exhibits of interest can improve visitors' QoE while keeping their visiting time within their expectations. Personalised applications can provide efficient filtering or guiding solutions to help visitors to find and focus on what they like. In this way, visiting a museum transforms into a personal experience, adapted to each visitor's interests, profiles and/or expectations. However, gathering useful data on visitors' preferences in the shortest time is crucial to provide them with the information they seek for from the start of their visit.

Since visit time constrains the visitor's experience while in the MIO, one can exploit time before and/or after the visit to prolong the total duration and offer opportunities for new types of experience. The experience can be extended before the actual visit to the MIO while the visitor prepares her trip, as well as after as the visitor shares the experience with other people.

Hage et al. [30] presume upon user preferences and suggest a personalised visit, optimised by walking distance and the exhibits that each visitor finds interesting. Roes et al. [31, 32] build upon the previous work by maintaining a dynamic user model and enriching the available palette of experiences by going online. Another approach [33] asks visitors to fill in a short questionnaire when they are handed a PDA guide. Throughout one's visit, the museum tour adjusts to their answers, among which is the visitor's age and time wished to spend for the exhibition. Neto et al. [34], present another approach where museum visitors were asked to play a knowledge game after a museum visit as an effort to increase visitors' learning on the museum's material and to test the knowledge acquired during the museum visit. Vassilakis et al. [35], present an approach which encourages its users to share their MIO experience with their friends on Social Networks during and after their visit. With this approach the visitors' interest would be kept alive even after the museum visit.

Each of the above mentioned approaches offers different benefits and can be used in different cases, all however sharing the same goal, enhancing the visitor's experience. Even though the previously described approaches seem promising, there are some issues to be addressed. To start with, the above mentioned works do not specify important elements such as the interest estimation accuracy and the effect that this has on the performance of the routing algorithm, nor do they take into account visitor's personalities, for the development of the recommendation and routing strategy. We think the latter is especially crucial, and complementary to interests. In order to provide

attractive and engaging content, relevant recommendations especially tailored for museum visitors should be applied.

In addition to the above, MIOs are not aware of the visitors prior to their visit. This means that user profiling as described in some approaches can only happen as soon as visitors arrive at the museum (as for example in [33]). While user profiling provides valuable insights, visitors have to devote a substantial amount of their time to fill in questionnaires, depriving them of time from their exhibition visit. Not to forget, there are also cases when visitors are not informed about the application's/game's existence, or even have minimal amount of time, resources or skills to play the game before or after visiting the venue.

To this end, an approach providing a high Quality of Experience (QoE) to the MIO's visitors, while exploiting every second of a visitor's visit time is essential. Visitors need to leave MIOs with an understanding of what the basic message was. To achieve that, visitors' personal interests should be taken into account in an effort to provide attractive content. By providing both engaging and fun content, visitors may have a good QoE and be willing to re-visit or recommend their experience to others.

1.1 Problem Statement

To summarise, based on the previously mentioned research findings we identify the following challenges when creating exhibition presentation applications for MIOs:

- Visitors spend limited time in an exhibition as a whole [12, 21-26] and only a couple of minutes per exhibit [27, 28].

- Visitors often fail to fully understand the message of the exhibition and sometimes leave with a misinterpreted or wrong idea [14].
- Often the Quality of the Visiting Experience is suboptimal, as previously mentioned.

These are crucial problems to be addressed, as MIOs' aim is for visitors to come back and revisit [39]. For destinations with an educational aim, acquisition of new knowledge is of high priority [29] and if the visitors fail to get the MIOs' message, their motivation is not fulfilled. This occurs more often in cases where visitors are part of a group visit (e.g. school groups) where they have to "go with the flow" and follow a pre-agreed schedule. As noted in [40], failure to satisfy occurs because of the failure to satisfy those motives of learning and the need for engagement.

Therefore addressing these challenges is crucial for visitors' satisfaction and an approach that best exploits visiting time, to help users understand and learn something new, offering an enhanced visiting experience, is of the essence.

1.2 Proposed Approach

To this end, we propose a new holistic approach. The approach is based on the three consecutive phases of one's visit to a MIO, being: (a) "before the visit", (b) "actual visit" and (c) "after the visit". Applications can be employed in any of these phases in order to enhance visitors QoE within the museum. Each option offers different benefits and can be used in different cases, all however sharing the same goal, enhancing the visitor's experience. We suggest the following basic pillars for each of the previously mentioned phases:

- **Preparation is important but not necessary (Phase A)**: Visitor profiling can be implemented prior one's visit. Usually, questionnaires and observation is the way to go when forming a user profile. However, visitors are not always willing to provide the time or the information needed when visiting a MIO. On the other hand, observation needs enough data to be collected in order for a user profile to be formed. We believe that estimating user's cognitive style, visiting style, and museum interests should be implemented in a fun, attractive and engaging way. Moreover, we suggest that potential visitors should be provided with personalization extraction tools prior to their visit, in order to gather a visitor profile while keeping their actual visit time intact. By acquiring the user profile and suggesting personalised content, visitors will spend their time in the MIO browsing exhibits of interest, minimising their time in front of those they do not find appealing. However, when this is not possible due to tool inaccessibility, time or skill restrictions, it should not affect the visitors' QoE.
- **Visit is vital (Phase B)**: Every second of visitors' time matters and needs to be of best use. Visitors should be able to find interesting and attractive content which will help towards understanding the MIOs message(s) in the restricted time of their visit. Even in cases where content personalisation is not feasible or practical and visiting time is limited, MIOs should be able to communicate a fundamental message to the visitors.
- **Keeping the interest (Phase C)**: MIOs should keep visitors' interest even after their visit. By doing so, visitors will be willing to re-visit and/or recommend their experience to others. Recommendation can happen through widespread methods and platforms as for example the use of Social Media.

Depending on each visitors' requirements we propose two alternatives, each one applied in different phases of a visit:

(a) **Visit elongation**, which applies during Phases A and C. In this case, MIOs exploit their visitors' time before or/and after their visit. This occurs when visitors are aware and use the available personalisation tools in advance of their visit and/or share their experience though any means (e.g. Social Media) after their visit. Chapter 2 presents this approach.

(b) **Message passing**, which applies during Phase B. This approach applies in cases when visitors have limited time available. On one hand, visitors may have restricted time available when visiting the MIOs exhibition, or may even be part of a group visit where they depend mostly on the group's schedule. In other, visitors may be unaware or do not have the time or skills to use the available personalisation tools before and/or after their visit. In such cases, we propose simple yet informative applications and tools to be put to use during one's visit in order to enhance their MIO experience. Chapter 3 presents this approach in detail.

One could also exploit both of the above approaches, creating a combination of the two in an effort to maximise the visitors QoE.

1.3 Contributions

This research makes a number of contributions to the fields of HCI, User and Visitor Experience, and Psychology:

- A framework for creating content for MIOs while keeping visitors engagement time to minimum. For each phase of the visit we provide suggestions on:
    - The visit preparation when visitor profiling can be acquired in an effort to minimise visit time and maximize QoE.

    - The actual visit and ways of communicating aright the MIOs basic message(s) in a matter of seconds.
    - Keeping the interest after one's visit and engage more visitors.
- The concept of nano-games and their use in MIOs, regardless of their topic, size and visitors.
- A direct result of this research is an entirely interactive nano-game informing its players about Hadron Therapy. The game, named HEAL and presented in the latter chapters, exploits the Kinect [41] sensor technologies by engaging movement recognition. The game offers a concrete example of using gestures to build a game which can be mastered in seconds.
- The evaluation method can be reused in order to evaluate other interactive travelling exhibitions, with only little modifications.

1.4 Conceptual Framework

Before proceeding it is important to define each of the major terms that relate to this work, so that the reader is able to understand the use of these terms in this thesis.

Venue: The place where an event takes place.

Exhibit: Individual item which is part of an exhibition.

Exhibition: An organised presentation and display of a selection of items.

Touring / Travelling Exhibition: An exhibition designed to be dismantled, packed, transported, unpacked and reassembled a number of times to a number of different places, so that interested parties can have an opportunity to visit and enjoy it.

1.4.1 What is a "Game"?

Giving a definition of "game" is quite difficult and complex [42]. However, efforts have been made in order to have an understanding of what a "game" is. The term can have either a very wide or a quite specific meaning depending on the circumstances used. For the sake of brevity, time and space, only a handful of definitions referring to "games" are going to be mentioned. Definitions of the terms "play" and "playing a game" will be elided.

Abt [43] tried to give a definition of "game" as:

> *"... an **activity** among two or more independent **decision-makers** seeking to achieve their **objectives** in some **limiting context**. A more conventional definition would say that a game is a context with rules among adversaries trying to win objectives."*

However, the definition was considered as not appropriate since it was too narrow and too broad at the same time, leaving out cooperative and solitaire games on the first case and including real-life activities such as war, elections and arguments in the second case.

[44] proposed their own definition:

> *"Games are an exercise of voluntary control systems, in which there is a contest between powers, confined by rules in order to produce a disequilibria outcome."*

In 1988, Kelley [45] gave his own definition of what a game is:

> *"A game is a form of recreation constituted by a set of **rules** that specify an **object to be attained** and the permissible means of attaining it."*

Parlett [46, 47] had a different perspective of games, dividing them into two categories, formal and informal games, with the latter being "merely undirected play or 'playing around'". On the other side:

> *"A formal game has a twofold structure based on ends and means:*
>
> *Ends. It is a **contest** to achieve an **objective**. Only one of the contenders, be they individuals or teams, can achieve it, since achieving it ends the game. To achieve the object is to win. Hence, a formal game, by definition, has a winner; and winning is the "end" of the game in both senses of the word, as termination and as object.*
>
> *Means. It has an agreed set of equipment and of procedural "**rules**" by which the equipment is manipulated to produce a winning situation."*

Costikyan [48, 49] presented his own definition of "game":

> *"A game is a form of **art** in which participants, termed players, make **decisions** in order to **manage resources** through **game tokens** in the pursuit of a **goal**."*

Crawford [50, 51] proposed another definition for "game using four factors:

> *"Representation. A game is a closed formal **system** that subjectively **represents a subset of reality**. (...) the game is complete and self sufficient as a structure. The model world created by the game is internally complete; no reference need be made to agents outside of the game. (...) The game has **explicit rules**. (...).*
>
> *Interaction. The highest and most complete form of representation is interactive representation. Games provide this interactive element, and it is a crucial factor in their appeal.*

Conflict. ***Conflict*** *arises naturally from the interaction in a game. The player is* ***actively pursuing*** *some goal. Obstacles prevent him from easily achieving this goal. If they are active or dynamic, if they purposefully respond to the player, the challenge is a game.*

Safety. Conflict implies danger; danger means risk of harm; harm is undesirable. Therefore, a game is an artifice for providing the psychological experiences of conflict and danger while excluding their physical realizations. In short, a game is a ***safe way*** *to experience reality."*

In 2003, [52] proposed his own definition of six points:

"A game is a ***rule-based*** *formal* ***system*** *with a variable and* ***quantifiable outcome****, where different outcomes are* ***assigned different values****, the player* ***exerts effort*** *in order to influence the outcome, the player feels* ***attached to the outcome****, and the consequences of the activity are optional and* ***negotiable****."*

The same year as Juul, [53] presented their definition of "game" as:

"… a ***system*** *in which players engage in an* ***artificial conflict****, defined by* ***rules****, that results in a* ***quantifiable outcome****."*

While each of the definitions mentioned is different than the others, they are also quite similar in some key points. Rules, conflicts and goals seem to be some of the basic elements of a "game". However, since this thesis is not intended to study the "game" definition, we will not go through the similarities and differences of the mentioned definitions.

1.5 Thesis outline

In the next chapters, we will present our approaches for visit elongation and message passing, along with some previous approaches published. Then, we describe our case studies that took place MIOs, exploiting these approaches. Finally, we discuss the outcomes of the case studies and make a short list of the future work to be implemented.

2 Visit Elongation

Over the past years several attempts have shown that personalised applications are promising for enhancing visitors' experience when visiting museums. As mentioned before, applications can be employed before, during, or after the users' visit in order to enhance visitors Quality of Experience (QoE) within the museum. Visit elongation refers to the extension of a visit by using applications and tools related to the MIO before (Phase A) and/or after (Phase C) the actual visit.

In the case of visit elongation before the actual visit (Phase A), MIOs provide applications and tools in several ways that are accessible to potential visitors. These applications serve a double purpose: obtain visitor profiling to be later exploited at the actual MIO visit to enhance the QoE, and attract more visitors. Visitor profiling should include information about user's cognitive style, visiting style, and museum interests in order to be later used to provide a fun, attractive and engaging visit.

In the case of visit elongation after the actual visit (Phase C), MIOs provide ways for visitors to share the visit experience with their connections and friends. This may happen in a conventional way with word of mouth marketing and/or by other alternatives such as sharing experiences on Social Media (e.g. Facebook, Instagram, Twitter, etc.). In this way, not only new visitors are attracted, but also past visitors' interest is kept even after their visit to the MIO.

2.1 Previous Efforts

Oppermann et. all [54] propose a guide exploiting users' interests and their position inside the museum, when visited. Users can prepare their tour before visiting the museum. The selected information is then used to their actual visit to provide supplementary content to the physical exhibits. To provide the needed information for each exhibit, a position tracking system identifies the current position of the visitor and updates the appropriate information on a personal digital assistant (PDA).

HIPS [55] is a similar approach, offering audio guidance by again using a position tracking system. As visitors move within the museum, the audio guide provides information on the exhibits using different reading styles, as if they are described from different perspectives. The length and duration of narration are tailored to the visitor's movement, meaning that people who move slowly into the space get more detailed descriptions.

Another approach presented in [33] asks visitors to fill in a short questionnaire when they are handed the PDA guide. Throughout one's visit, the museum tour adjusts to their answers, among which is the visitor's age and time wished to spend for the exhibition. For example, in case a visitor falls behind, the tour guide will suggest exhibits to skip, while if more time is available, additional exhibits will be recommended. The guide also offers sharing recommendations, comments and ratings with other visitors as well as locating them physically in the space.

Approaches [30-32] propose a museum guide where visitors create their own profiles of interest that are later used to generate personalised tours. Before visiting the museum users can create an online account and browse through artworks and concepts, rate artworks, view recommendations and create virtual tours. User preferences are stored in the user profile. When users visit the museum, they can login to the CHIP Artwork

Recommender / CHIP Tour Wizard and be presented with a list of personalised tours. As soon as the visitor submits an exhibit rating or alternation in their route, the guide adapts the tour on the fly, optimising in terms of walking distance and exhibits to visit.

In [56], visitors are asked to take a quiz, either before or as soon as they visit the museum. Through a small set of indirect questions, visitor preference information is gathered to initialise the visitor's profile. Based on this profile, the CHESS system chooses the appropriate story to present to its user. Users are also able to trigger menus and actions buttons, with which they can adjust the story to be presented next.

Other approaches include [57] using personas to augment visitor experience with personalised mobile storytelling. Personas are detailed descriptions of imaginary people constructed out of well-understood, highly specified data about real people [58].

[59] recommend 3D personalized route planning. Pair-wise comparisons are used for preference judgment, indicating user preferences. Ontologies with metadata weights are exploited in order to model user's preferences.

GECKOmmender [60] is another approach, using a mobile system for personalised theme and tour recommendations in museums, based on a digital site-map representation. Star ratings provided by visitors for viewed items are used to calculate recommendations for unvisited exhibits.

FIRSt [61] is a content-based recommendation system integrating user-generated content through social tagging in a classic content-based model. Users express their preferences by entering numerical ratings as well as by annotating items with free tags. Tags form a folksonomy whose structure is analysed to build more precise predictions of interests.

2.2 Social Media Engagement

While all the above approaches are promising, they still require forming a user profile. This can be obtained by asking directly, mainly by using questionnaires, or by observation. In the case of museums, visitors are not always willing to spend the time or provide the information needed. There are also cases when visitors are part of a group visit and need to stay with their group. On the other hand, observation needs enough data to be collected in order for a user profile to be formed.

Social media is getting all the more popular [62] with over 3.6 billion people using social media worldwide in 2020 [63, 64]. Information shared on social media can be of great importance as it could provide a good basis for use in personalized applications. In most social media platforms, users have to provide some basic personal information including their name, sex, and birthdate in order to register. As time passes and users engage more in their social media account, they tend to give more information about themselves and their interests. For example, preference information can be acquired from one's likes or reaction to comments, photos, pages, and groups. The number of connections can also provide information about one's personality. One can assume that if a user has lots of hundreds of connections (friends), then the user is quite sociable. Preference information can be also acquired from one's likes or reaction to comments, photos, pages, and groups. In Facebook for example, one can react to a post to express how they feel about it (like, love, care, laughter, surprise, sadness and anger).

Keeping in mind that museum visits are short in duration, we believe that user profiling should be implemented prior to one's visit. In this case, valuable information will be gathered beforehand and exploited later to personalise the visit and enhance the QoE within the museum. In addition to that, visitors will spend their time entirely to the exhibition(s) they wish to visit. To attract and engage museum visitors, the approach

should be both entertaining and interesting, as mentioned above. We also agree that user profiling information should be gathered indirectly and quickly [65].

To this end, we suggest implicit profiling formed through explicit domain-related actions. We propose a new approach to estimate user's cognitive style, visiting style, and museum interests through the use of a social networks game that will be used prior to one's visit [66-68]. In-game preferences translated to real-world preferences will form each user's cognitive profile. In this way, important personal information is acquired before a user's visit, with their consent. This information is used to create user profiles and compute recommendations before a museum visit. Each user's profile will be later used, when they physically visit the museum, to provide a personalised visit guide in an effort to enhance QoE within the museum.

It should also be mentioned that social media is not only used before one's visit, as a means to gather personal information, but also during and after their visit. User's experiences are linked to social networks, including comments and pictures, in an effort to engage their social network connections. In this way, users create their own visit diaries, while sharing them with their social friends. By engaging visitors before, during, and after their visit, we provide a holistic experience.

The above-described approach to museum personalisation is thought to improve visitors' QoE. User's cognitive style, visiting style, and museum interests are gathered through the use of a social networks and used to provide visitors with a personalized guide to enhance their QoE within the museum. Our approach to museum visit personalisation consists of both recommendations and adaptations and relies on three innovative pillars:

- Implicit user profiling implemented through explicit domain-related actions.

- Use of cognitive profiles as a visitor's representative way of thinking and personality traits [69].
- Museum experiences are linked with social networks.

2.3 My Personalised Museum Experience

To evaluate the above approach, a component bundle called "My Personalised Museum Experience" in the context of the "BLUE experiment of the EXPERIMEDIA FP7" project [70] was created. In short, our approach extends a conventional MIO visit by exploiting Social Media games that reveal visitors' visiting styles and cognitive preferences, prior to their visit. This information can be later used to enable personalised routing and tailored exhibit descriptions during visitors' venue visit. The involved components handle recommendations and respectively personalization, and include:

- A social media game exploited both as a source of profiling information (cognitive profiles, museum interests and visiting styles) as well as a way to attract more visitors.
- A mobile application as a personalised electronic guide that visitors will be given during a museum visit.
- A tailored recommendation engine and personalised exhibition descriptor, components that handle recommendations and respectively personalisation for each user.

In our case, the social media game developed is called "My Myseum Story". "My Myseum Story" is a social web-based application, developed for use in Facebook [71]. The Facebook social media platform was chosen since it is the most popular network [63]. Based on [72], more than 800 million users play Facebook connected games every

month. Hence, Facebook seemed to be the ideal social media network to host and promote such a game. Throughout the "My Myseum Story" gameplay, users' cognitive profile, visiting style and museum interests are estimated. All three are then put in use once a user visits the real-life MIO in order to provide a personalised guided tour and enhance the QoE within the MIO. To supplement the social network game, a mobile application named "My Myseum Guide" (MMG) was also developed. The "My Myseum Guide" application offers visitors smart routing recommendations and personalised exhibit descriptions and recommendations based on their extracted cognitive profile. Visitors can also share their experience with their social media contacts though the "My Museum Guide" mobile application. Figure 2-1 shows the "My Personalised Museum Experience" architecture.

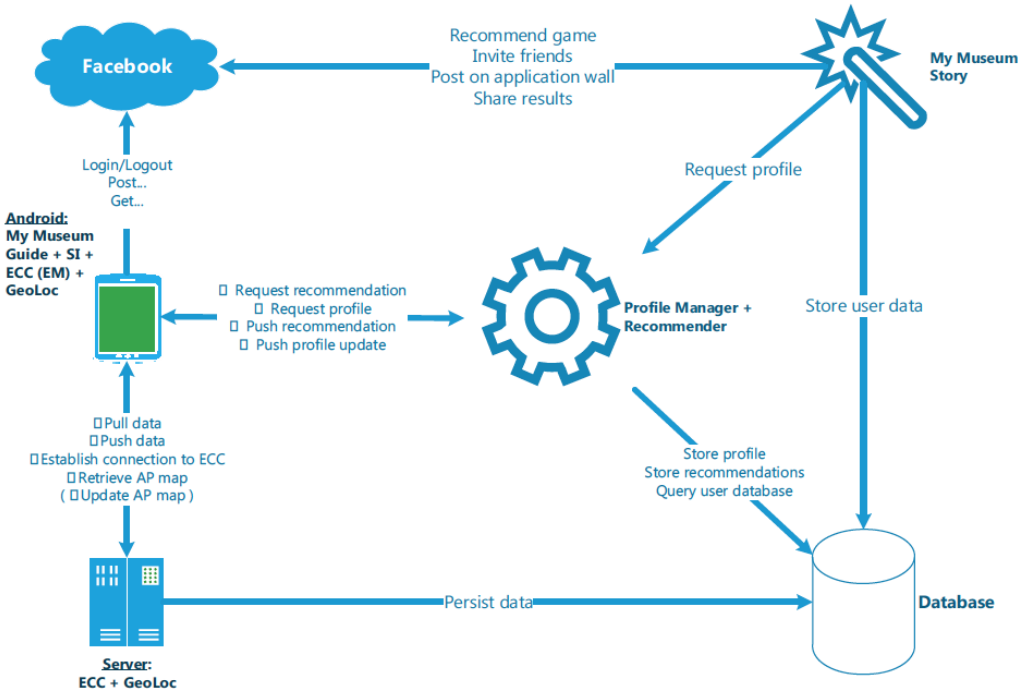


Figure 2-1. My Personalised Museum Experience architecture.

2.3.1 "My Museum Story" (MMS) Game

"My Museum Story" (MMS) is a Facebook game giving its users the ability to populate their own virtual museum with exhibits. To do so, players need to play a variety of mini-games in order to win exhibits and coins. Exhibits are used to complete the exhibitions, while coins can buy museum expansions, unlocking and adding more exhibition rooms. Certain objects in all exhibitions can only be collected from a physical visit at the museum. MMS is exploited both as a source of profiling information (cognitive profiles, museum interests and visiting styles) as well as a way to attract more visitors.

Before start playing, players need to make some decisions involving their character in the game and the different tools and equipment they wish to carry. In particular players decide about the character they want to use in the game, its traits, the pet following the avatar and the tools they might need. Every character, tool and pet corresponds to different values of the cognitive style. Figure 2-2 shows the providing options for character and pets.

Figure 2-2. Avatar and pet choice screens.

The choice of character provides information about the user's cognitive style. For example, selecting the TV Persona character indicates an extravert personality, while selecting the Alien character indicates an introvert personality. Tools and pets have different abilities that can be used in the game. The choice of pets is also related to different aspects of the cognitive profile (Intuition-Sensing, Extraversion-Introversion,

Judging) and of the personality of the user. Same applies for the choice of tools, which is related to the cognitive profile aspects of Thinking-Feeling and Judging-Perceiving. Table 2-1 provides the list of available options users are offered along with the cognitive profile aspect that each one reveals.

Table 2-1. List of options MMS users are offered along with the cognitive profile aspect that they reveal.

	Item	Aspect Revealed
Avatar Choices	Scientist	Introversion
	TV-Persona	Extraversion
	Judge	Thinking
	Diplomat	Feeling
	Engineer	Sensing
	Artist	Intuition
	Old-wise	Judging
	Alien	Introversion
	Rapper	Perceiving
Pet Choices	Dog	Intuition
	Cat	Sensing
	Monkey	Extraversion
	Fish	Introversion
	Owl	Judging
Tool Choices	Book	Thinking
	Clock	Judging
	Disco Ball	Perceiving
	Heart	Feeling
Museum Template	Open Layout	Fish visitors
	Linear Layout	Ant visitors
	Free Layout	Butterfly visitors

As soon as the player chooses the above aspects, then she can enter an empty museum space that needs to be populated with items and decorated according to her preferences. There are three virtual museum templates that the player can choose from, each of which indicating the user's visiting style, as described in [36]. The first museum template was the open museum, which provided an open solution and it was easy to quickly see all the objects and the available rooms. The open museum was stipulated to correspond to Fish visitors. The second museum template was the linear museum

layout, which had exhibition rooms and exhibits organised in a linear fashion and was thought to be best suited for Ant visitors. Finally, the third museum template was called the free museum and exhibitions and exhibits were placed in different spaces without a predetermined path. The users could move as they pleased and place their exhibits freely in the museum space. This museum template was targeting Butterfly visitors. There are also three decoration styles to choose from (i.e. classic, modern, pop) as well as different background music options.

Figure 2-3. MMS game screen. User has already won several exhibits.

In order to collect the items for their museum exhibition, players need to complete successfully games of little complexity, defined as mini-games by [37], in order to win each item. To do so, players can move in front of the empty showcases and frames and choose between games of different types (i.e. luck, skills, knowledge, memory, brain

games, etc.). Figure 2-3 shows the player's game screen. In this specific screenshot, the player has already won and placed three exhibits on the available showcases. When starting the game, all showcases are empty. Items are from different thematic categories (i.e. depending on the museum exhibitions the items can be from exhibition number 1, 2, etc.) and can be collected as awards when winning a mini game. When users complete successfully a mini game they are offered with a set of awards in order to chose the one they prefer to acquire. The choice of items is recorded and stored as it reveals the player's personal interests for the real museum exhibitions. For example, users who decide to collect ancient statues instead of old machines and tools might prefer the exhibition on ancient cities and civilizations to the exhibition of old machinery and tools. Therefore, the items that the user finally chooses for their museum, should give us an idea of their "content based" interests. By exploiting this information the mobile application can guide them accordingly later during their actual museum visit.

Users gain experience by acquiring all the more exhibits and by expanding the museum. An experience bar showing the user's current experience, as well as the remaining experience that needs to be gathered to reach next level, is visible on top of the screen. Short instructions are available when users click the question mark icon positioned at the top right corner. A preview of a museum map is always visible at the bottom left corner in order for users to know their location in the virtual museum. On the bottom right corner, users have the opportunity to enter their inventory and browse through their undisplayed exhibits (Figure 2-4). Finally, user's friend list is available at the bottom of the screen, offering also the option to add more "My Museum Story" friends from their social network.

Figure 2-4. Choosing a mini-game to play for a chance to win an item in MMS game.

Having player's personal interests computed from their cognitive styles and personal interests, both inferred from them playing the MMS game, a set of recommendations should be available to the users during their actual museum visit. Recommendations are issued from a base set of Point of Interests (POI) and Actions. These have been built by analysing the available museum exhibitions and typical actions undertaken in a museum or on social media. The number of recommendable POI depends on the museum. The gift shop and cafeteria can also be considered as POIs in a museum. Actions range from taking a picture over enjoying a meal to leaving a comment using the mobile application. In order to be able to personalise the recommendation, each recommendable item, POI or Action, carried separate descriptions for each of the cognitive profiles. As the cognitive profile of a user is immutable, the personalisation is also stable, thus allowing for a concrete user experience.

2.3.2 “My Museum Guide” (MMG) Mobile Application

To present recommendations to the visitors in a succinct way, a mobile application, called “My Museum Guide” (MMG), was implemented. The MMG computes recommendations in the form of predictions. These are then provided in the form of a sequence of POI to the visitor [67]. Figure 2-5 is an example of the recommendations shown to a user for different exhibitions.

Figure 2-5. MMG user recommendation screen.

The MMG application offers visitors smart routing recommendations on their mobile device for exhibitions as well as personalized exhibit descriptions and exhibit recommendations based on their extracted cognitive profile and content preferences. Users can log into their Facebook account, tying their experience with it if they choose to. Upon logging in, the MMG will retrieve their previously stored personalised recommendation from the server. Once computed, the sequence of personalised recommendations will be kept up to date and relevant to the visitor’s current activity and location. Figure 2-6 shows a visitor interacting with the MMG application during her

museum visit. The visitor may indicate when she has visited an exhibition or completed a recommended action. In that case, recommendations will be removed from the recommended sequence and, exhibitions, will be available to the visitor to comment on and attach pictures.

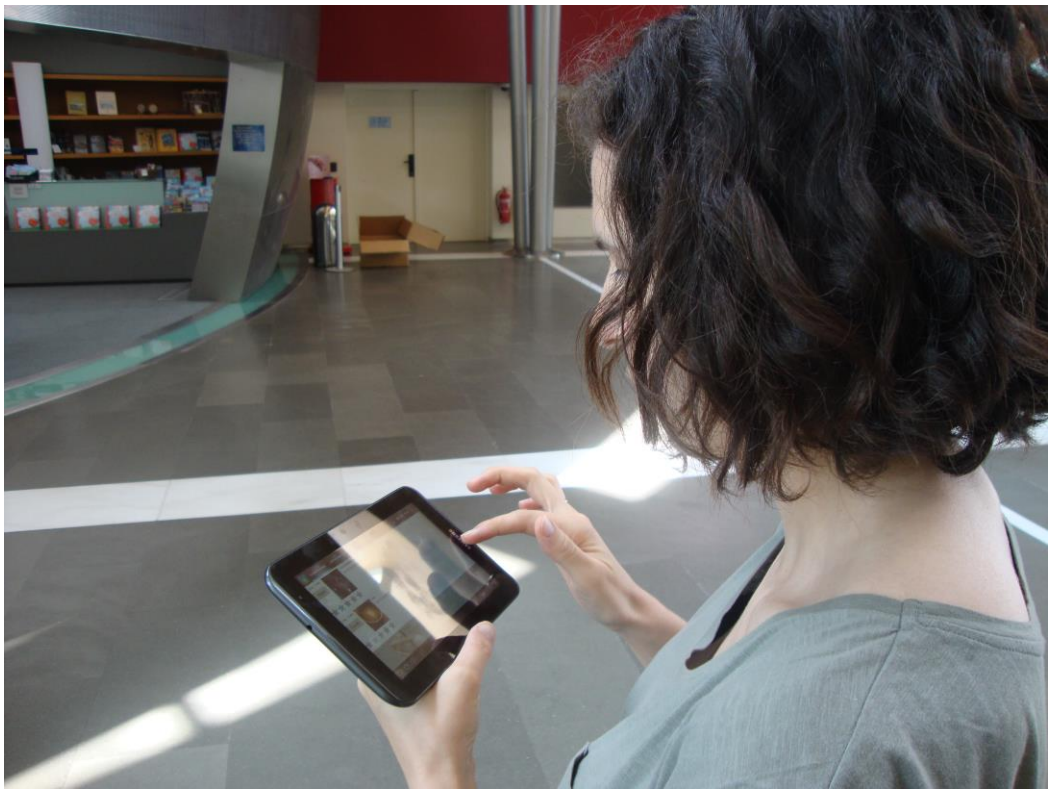


Figure 2-6. A visitor viewing the exhibit suggestions as recommended by the MMG application.

Visitors can also mark favourite exhibitions and other museum-related data into their personal "Story Line", which they can later on share with friends in their social networks. By doing so, they extend their conventional museum visit. Linking user's experiences, including comments, and pictures into social networks fosters socialization and entices interest throughout a network rather than localizing experiences to individuals (Figure 2-7).

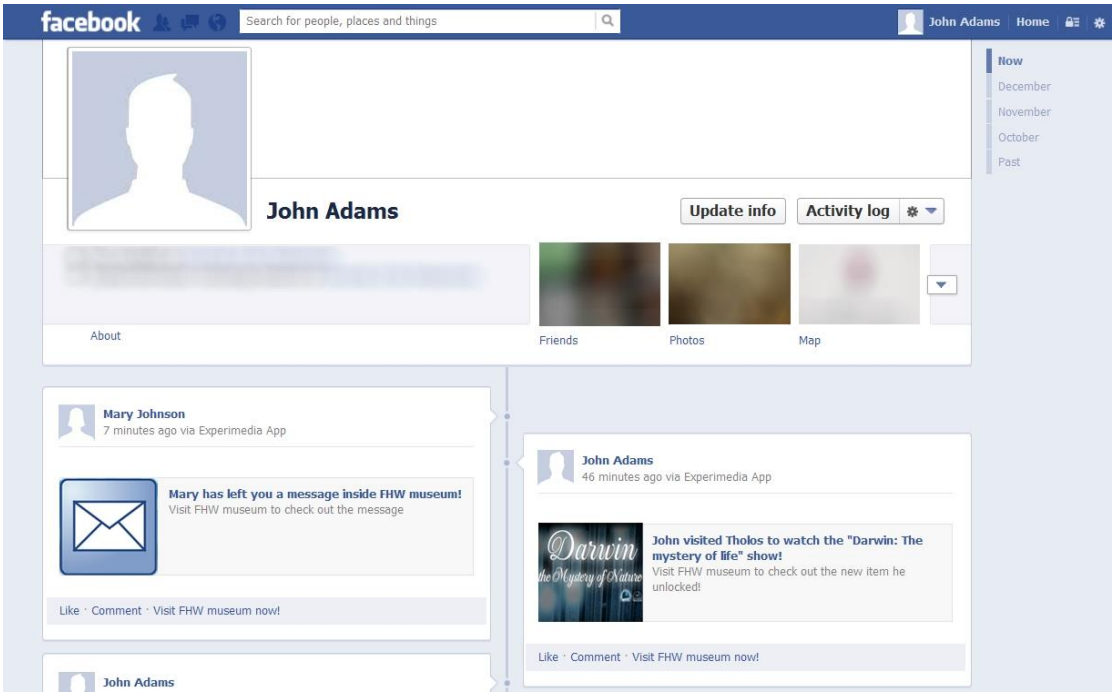


Figure 2-7. User's timeline after sharing an update on their visit to the museum. The user has also received a message from a friend during their visit at the museum.

2.4 Visit Elongation Evaluation

2.4.1 Scenario Background

The BLUE experiment was conducted at the Foundation of the Hellenic World's privately owned cultural centre in Athens. Chosen as one of the three experimentation venues of the EXPERIMEDIA project [70], the Foundation of the Hellenic World is an ultramodern cultural Centre and museum, which fosters visitor experience through technology (e.g. through interactive exhibitions, virtual reality tours, and educational programs).

During the experiment, visitors were able to use both the MMS and MMG applications, part of the "My Personalised Museum Experience" application bundle. By using MMS, users could setup their cognitive profile and preferences regarding things they like as

well as their visiting style. This information would be used to create personalised content descriptions based on their cognitive profile and content preferences. MMG would later present on their mobile device this content to the users along with smart routing recommendations for exhibitions and content to see during their actual visit at the venue. In MMG, visitors could also mark favourite exhibitions and other museum-related data and compile them seamlessly into their personal "My Visit", which they could later on share with friends in their social networks.

While conducting the experiment, visitors' behaviour when using the "My Personalised Museum Experience" application bundle and especially their reactions against recommendations was recorded and analysed. After the visit, visitors filled in questionnaires related to their Quality of Experience (QoE) providing direct feedback on the experiment.

2.4.2 Scenario Story

Before the visit, visitors were able to play the MMS game. Visitors did not need to be physically at the museum space to do so. The application was available through Facebook or, after registration, as a simple web application for those users that do not have a Facebook account. The application's goal was to extract user's cognitive profile, their content interests in regards to the museum exhibitions, as well as their perceived visiting style, while entertaining them through a series of mini-games.

During the visit, visitors were in the physical space of the museum. A mobile device running the MMG application was provided to them in order to assist them navigate inside the museum. The mobile application allowed them to retrieve their cognitive profile and content interests, mainly from the MMS application, and to log into their Facebook account. The MMG application then recommended an itinerary to the visitor, using their profile and interests, as well as some additional initialisation data (e.g. "how

much time do you plan to spend inside the museum?"). This itinerary consisted of different exhibitions and timeframes, determined by the content interests and time restrictions the visitor had. In addition, the mobile application provided information on exhibition items based on the visitor's cognitive profile. MMG also allowed the visitor to "keep" a digitalised version of their experiences inside the museum, by assembling images and keeping digital notes about the visited exhibitions. The data gathered by the visitor during their visit formulated the visitor's personal museum "My Visit", which at the end of their visit could post on Facebook and share with their social circle.

After the visit, visitors were asked to fill in a user satisfaction questionnaire. They could also share their experience (their personal museum "My Visit") in Facebook through a social functionality that MMG provided. Finally, if deemed necessary, visitors could be asked to participate, if they wished, in a structured interview to measure the quality of their experience.

2.4.3 Experiment

Four experimental sessions were conducted in June and July 2013 at the Hellenic Cosmos of the Foundation of Hellenic World (FHW) in Athens. The total number of participants was 30, 15 males and 15 females with an average age of 30. Of the 30 participants 6 people visited alone, 17 with one or more friends, and 7 with family members (there were also two children visiting with their parents but they were not included in the sample due to legal constraints). Consistent with the literature describing how people usually visit museums in a group (Antoniou, 2009), our sample also reflected this trend. In addition, data collected from participating families is of significant value as data regarding family museum visit behavior is scarce. The experiments were advertised on Facebook (through researchers' personal pages asking

friends to share). Thus, almost all participants found out about the experiments on the social network and responded through it.

The experimental procedure required invited visitors to first play the MMS Facebook game, then visit the museum and use the MMG mobile application (Figure 2-8), and finally fill in a questionnaire. The experiments provided data that could be used to evaluate the experiment both qualitatively, since there were many open-end questions, and quantitatively.

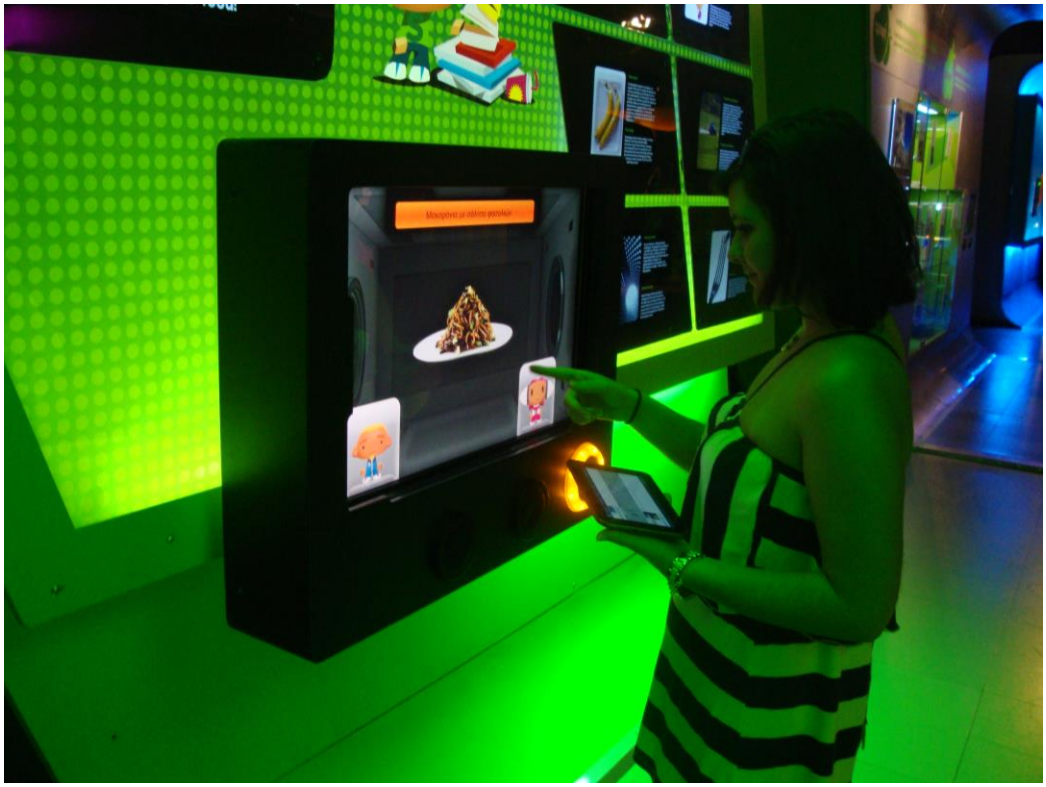


Figure 2-8. A visitor interacting with an exhibit as suggested by the MMG application. Visitor is holding the tablet running the MMG application during her visit.

Visitors were free to play with the MMS game any time before their visit. For those that did not do so, laptops were available on site in order to play MMs just before the visit. Participants having already played the MMS game were provided with a tablet running the MMG application as soon as they entered the museum. MMG application allowed its users to log into their Facebook account, tying their experience into their social network

if they chose to. Upon logging in, personalised recommendations were retrieved from the "My Personalised Museum Experience" server. The personalised itinerary, including a sequence of recommended POIs, was kept up to date and relevant to the visitor's current activity and location. For each POI, the visitor had the opportunity to comment and attach pictures, hence building their own visit diary. They could also indicate when they had visited an exhibition or completed a recommended action. At the end of their visit, visitors could choose to upload their visit diary on social media (i.e. posting their itinerary and pictures, including comments, as Facebook status and gallery). After the visit, participants were all asked to respond to a questionnaire before leaving.

2.4.4 Facebook Game Results Analysis

2.4.4.1 Gameplay Choices

All participants, apart from 3 that did not have a Facebook account, had played the MMS Facebook game. From the 9 available avatars in the game, three were never chosen (TV persona, Diplomat, Rapper). From the remaining 6, the Mad Scientist was the most popular since 7 people chose it. This clear preference might be due to the position of the item in the game's selection screen, since it was the very first avatar (Figure 2-2). As for the available pets, Goldfish was never chosen. The dog was the most popular being chosen by 14 people. From the tools, the Book was the most popular (14 choices). Both the Dog and the Book were the first items in each selection screen.

The clear preference for the first items in each category observed, could be explained by the known preference of the western world users for the top left corner. For this reason, any new version of the game should vary the position of the items in the choice tables.

Despite the "first item" preference, participants were asked to explain the reasons for their choices. As it was found during pilot testing, the pictures of characters, tools and pets alone were not sufficient to stress the main feature we would like people to look at,

i.e. the one related to a cognitive style dimension. In order to increase the success rates of the pictures chosen, a short sentence was be placed under each picture to show users the main characteristics of each character, pet and tool. For example, the Diplomat picture should be accompanied with the text "I like to avoid conflicts", as the concept of a diplomat might mean different things to different people. From the participants' answers it was clear that this practice was very useful and people did read the text in order to make their choice. After all, 15 out of 20 people explicitly stated that their choice of characters/pets/tools reflected their personalities.

2.4.4.2 Gameplay Usability

Most users did not face any problems while playing the game. In addition, 26 out of 27 people reported that the game was easy to play, 24 out of 27 said that they enjoyed the game and most people managed to collect exhibits by playing with the average number of exhibits per player being 7. Almost half of the users invited their Facebook friends to play the game (13 out of 27) but only 8 out of 27 reported their scores on their profile on Facebook. As for improvements, most participants suggested that the game graphics could be enhanced (some found them old-fashioned). Additionally, some participants mentioned that they had navigation problems, although a map was used in the game to show players their exact position within their museum. As for other points for improvement, a few people said that the mini-games were easy and they would prefer more difficult ones, while others suggested adding a short description to each game. One participant suggested adding a tablet version of the game.

2.4.4.3 Estimation of Cognitive Style by Facebook Game

One of the main hypotheses of the present study was whether a social networks game could reveal people's personality traits, amongst them the cognitive style. In particular, there are 4 dimensions of opposing traits: Extraversion-Introversion, Sensing-Intuition, Thinking-Feeling and Judging-Perceiving (following the MBTI classification). For

Extraversion-Introversion, the game correctly estimated this dimension with 69.2%. For Sensing-Intuition the success rate was 58.8%, for the Judger-Perceiver 77.7% while the lowest score was for the Thinking-Feeling dimension with only 55%.

The game could in many cases correctly estimate player's cognitive style, with success rates of 55% to 77.7%. This seems promising as this estimation was reached after only three choice screens (Character/Pet/Tool). We believe that the game is moving in the right direction and more features need to be included in order to make it more accurate.

2.4.4.4 Prediction of User Interests by MMS Facebook Game

21 out of 23 participants reported that their choice of exhibits reflected their actual museum interests (91.3%). The MMG application used information from the MMS game and people's exhibits choices in order to suggest exhibitions. People reported their preferences for the 8 exhibitions available at the FHW. Comparisons between the MMG recommender ratings in a 5-star rating scale (Figure 2-5) and the users' self-reports on their interest levels showed that user interests were adequately predicted and MMG suggested best suited exhibitions.

Regarding the choice of exhibits, only one person reported choosing items from all the available categories, and one more claimed having not really thought about it. All other participants made conscious choices of exhibits, picking them according to their interests, and had clear reasons for their choices.

Despite the fact that for copyright issues the images were processed and were not very clear, users' choices did not seem to be largely affected in the MMS game. It also seems that a game that uses such features can accurately predict people's interests inside the museum.

2.4.4.5 Prediction of Visiting Style by Facebook Game

Most participants reported a preference for an Ant visiting style in museums. Three museum templates were used in the game, since it was hypothesized that they could reflect visiting style preferences. From the available museum templates, most people chose the free museum (11 people), 10 people chose the open museum and only 1 chose the linear museum. When the museum templates choices in the game were compared to the interview questions about visiting style preferences, it was found that visiting style was correctly predicted from the template choices in 6 cases and wrongly predicted in 16 cases.

It was thus found that we could not accurately predict the preferred visiting style of visitors by simply using their game template preferences. However, the nature of the images used in the game might have affected users' choices. This is because some participants reported during the interview that the shape of the museum template was very important for their choices, more than the practicality of that template.

In an effort to avoid the issue of image aesthetics, in a next game version, the templates will need to be very carefully designed.

2.4.5 On-Site Results Analysis

Below the analysis of the results achieved from the experiment conducted at the Hellenic Cosmos of the FHW is presented.

2.4.5.1 QoE: Overall Satisfaction and Evaluation

A big proportion of the participants, 73% (11 out of 15), reported following the recommendations as suggested by the MMG tablet application. When asked about their overall feedback about MMG, 75% (15 out of 20) of the participants were very positive about its use, and only 10% (2 out of 20) mentioned that MMG should provide more

information. Participants were also asked if they would prefer to visit the museum with or without the MMG recommender. 82% (22 out of 27) of the participants answered that they liked having the tablet running the MMG application and the quality of their experience was enhanced.

Participants also expressed the importance of seeing all relevant exhibits in a museum and not miss information important to them (4.6/5 star rating). Avoiding visitor traffic and effective movement patterns scored less with a 3.9 out of 5 star rating.

2.4.5.2 Success of On-Site Recommendations

When participant's self-reports were compared to the MMG tablet application recommendations, it was found that from the total of 250 recommendations, MMG was successful in 57.9% of the times (average success rate). However, when individual categories were studied separately, MMG was particularly successful to suggest certain types of exhibitions like Ancient Cities (61.3%) and Biology – Darwin (65.2%).

It is interesting to note that MMG was also suggesting activities like a short break at the museum café or gift shop. These recommendations were not based on the individual profiles but only on the exhibitions time schedules and gaps between shows, as FHW hosts numerous 3D movie exhibitions.

2.4.5.3 Photo Option and Online Visit Sharing

Using the MMG tablet application, users could take photos from their visit and upload them to their Facebook account. Although only 39% (9 out of 23) of the participants answered that they would upload these pictures or that they already had, at the end of the interview when asked about their general views of the experiment, most people said that they really liked the photo feature and most took pictures using the tablets during their visit. The finding is not contradicting, since people might want to document their visit, but not publish it on social networks, to protect their privacy. In addition, our

average participant age was 30 and older adults might have a different approach to privacy issues than younger adults, especially regarding information shared on social networks. Nevertheless, the photo option seemed to be useful and well liked. The only addition would be to provide the option of sharing the information on Facebook or keeping it for personal use.

2.4.5.4 Tablet Usability

Almost all users stated that the MMG tablet application was very easy to use. Only one said that it was sometimes not so easy. All (100%) of the participants explicitly stated that the application was enjoyable and 90% (19 out of 21) of the users mentioned that the information was presented in a satisfying manner. When asked if a map would be useful, 74% (17 out of 23) of the participants agreed. While the MMG featured a map, it was not activated due to an unresolved problem as to how best switch floors when a user transits between floors within the venue. To not confuse users, it was chosen not to display a map.

Participants were also asked if the recommendation notations were clear and if they would make any changes. Most participants were satisfied with the notation system used (i.e. stars for each exhibition). One participant mentioned that he did not realize that these stars were the recommendation's scores and another said that perhaps a bar with percentage of interest would be more useful than the stars.

Finally, all participants were asked about other information they would like to have. The most frequent requests were a map, more pictures from the exhibitions, and three participants requested a feature to rate exhibitions themselves.

2.4.5.5 Effect of Personalization and Content Adaptation

Although all content provided to the users was adaptive and prepared for the different cognitive styles, the users did not realize this adaptation. Although they were happy

with exhibition descriptions, most of them did not realize that their partners and friends had different descriptions and often they did not open the content pages that provided more in depth information for each exhibition. Actually, only 6 out of 23 checked their friends' screens and saw that there were different stars provided to different users.

The observations are consistent with literature describing how users do not read text [73]. It seems that adaptive content, at least in the form of text, is not necessary as users do not read the description. However, users did notice the pictures used for the different exhibitions and some asked to have more pictures from each exhibition. This observation might imply that adaptive content is relevant but in alternative forms to text, like audio or visual content. However, further research is required to determine which form of adaptive content is best suited for the different types of visitors by cognitive styles.

2.4.5.6 Group Visitors Evaluations

Since most museum visitors visit in groups, it was important to record group visitors' behaviour with the MMG tablet application. Participants were asked to describe their behavior within the museum and whether they did what MMG suggested or followed the group's wishes. Only one participant mentioned that he would not follow the group and continue with his personal preferences as reflected on the MMG suggestions. Similarly, only one person said that he only followed the group's decisions. It seems that most group visitors tried to combine different suggestions for the different group members and proceed accordingly. However, the situation was very different for participants visiting with children, since they all said that they only did and would do what the child wanted.

2.5 DISCUSSION

The two applications developed within the framework of Experimedia Blue were tested with real users at the FHW in four separate sessions. The sampling processes replicated the processes the museum could apply in order to attract new visitors, advertise exhibitions, and collect relevant information for user profiling. Having used Facebook for sampling purposes, the networks efficiency was also observed since people responded.

Users found both applications to be highly usable and enjoyable. As users mentioned, it was very interesting to link people's personalities and actions prior to the visit with the physical museum visit. The novel approach of using a social networks game for museum visitor profiling was successful in numerous ways but most importantly because it opens a road towards the exploitation of the vast quantities of information available in social networks and its use in adaptive technologies. Overall, visitors QoE has been enhanced and their final impression within the museum was very good. Roughly, 82% liked using the tablet with the MMG application, 75% had a positive impression using the MMG recommender and 73% actually followed the recommendations.

Those results, despite an average precision of recommendations of 58% (on exhibition ratings, on a 1-5 scale) are very encouraging knowing the constraints induced by the museum venue and the little amount of data exploited for profiling users. With the MMS, we were able to show with a high success rate (91% resp. 67%) that user interests and cognitive style could be predicted from a simple game targeting museum topics.

Evaluation showed that the MMS Facebook game can reveal players' cognitive styles. The data collected in the study provided partial support for the above hypothesis. As discussed above, this first version of the game only explored the possibilities of a game that could reveal cognitive styles. There were clear tendencies towards this direction

that definitely require further development. The game only used three screens to calculate players' cognitive styles. We believe that different features that should be added to the MMS game that can provide further information and possibly more accurate results. The main challenge for designing the MMS game was to identify the key pictures to best reflect the different dimensions of the cognitive style. Keeping in mind that for the proper estimation of cognitive style, a highly trained psychologist should interview a person over a significant amount of time, the MMS game had to significantly accelerate this process by reducing it to item selection in only three screens. Considering the above, the results were more than satisfying and promising for further development. In addition, this is a highly novel approach, not simply because it attempts to estimate users' cognitive styles from a simple game, but also because information from social networks can be used in a user profiling process in adaptive systems, whether these will be used in cultural heritage, education, etc.

The MMS Facebook game can also predict players' museum interests. Most users reported that they chose items that reflect their personal interests and not simply because of item aesthetics or image quality. Information deriving from social networks can be particularly valuable. Knowing users' interests information can be tailored and directed accordingly. In particular, museums can use this information to target specific groups in order to advertise different exhibitions but also in order to support the actual museum visit by significantly enhancing the visitor's QoE.

In addition to the above, the MMG recommender can provide the best-suited exhibitions for each user. Based on the game data, MMG was indeed successful in providing the most appropriate exhibitions to the different users but for some and not all exhibitions. So far, MMG has been designed for single visitors, focusing on individuals and single cognitive styles. However, as known from the literature but also observed during our experiments, visitors usually visit in groups. MMG could significantly increase its success

rates by combining the information of the individual cognitive styles and the information about the group members in a single visit. For example, exhibition 1, 2, and 4 will be the best for user X. Knowing that X is visiting together with Y and their favourite exhibitions would be 1, 2, and 5, MMG could suggest exhibitions 1 and 2, informing the users that these would be the best choices for their group. These future additions would hopefully make it suitable for group visits, hence, targeting a known technological problem faced by museums regarding group visits and provided content.

However, evaluation did not show that Facebook game players' choices of museum templates can reveal their preferred visiting style for a physical museum. The main reason seems to be the aesthetics of the images used, since certain images seemed to attract the majority of preferences. Attempting to capture the preferred visiting style before one's visit seems to be a very demanding task and alternative ways should be further explored. This is a field for future exploration that remains to be studied.

2.5.1 Challenges and Limitations

The Experimedia Blue team faced numerous challenges during the design, implementation and testing of the applications, mainly due to the nature of the venue as the FHW is not a traditional museum hosting object-based exhibitions. In addition, the content of the exhibitions was highly targeted at students. The information was simplified and generic, mainly in the form of 3D movies. Only one exhibition was using interactive technology to present environmental issues. The layout of the museum and the nature of the exhibitions (i.e. highly targeted, film form, specific time schedule) have affected the outcome of the experiments since none of the users was of school age. Most users were adults invited through Facebook and they found the exhibition content of a school level, even childish. This had enormous implications on the present work, as, although someone might like Biology, they could give the Darwin exhibition a low mark

because it was not of the desired depth. Combined with the fact that most users did not access, read, or even notice the adaptive content, adaptivity at this level might not be meaningful. Adaptation is something to be considered beforehand, to cater for different target groups and different views or interpretations of the exhibition's message. Altering text-based information does not have a strong effect on the experience. However, recommendations are certainly useful. Given that the museum was a small one with a lot of limitations on the visit (hours, presentations, ticketing policy) the overall visitors' feedback is positive. For a large museum, with lots of exhibits (more than what an average visitor would be able to view in a day's visit) and more freedom of movement, the impact would have been even greater. In larger museums, such a system would be particularly useful since it would allow curators to know visitor interests before their visit, suggest routes inside the museum to avoid visitor traffic, and provide opportunities for both visitors and museums to connect the visit with social networks.

The results obtained in this first experiment indicate interesting tracks for future investigations. However, the small sample used in the experiments (N=30), raises issues of experimental validity. We can assume low external validity for the general population for two main reasons. The small sample size is the first, although the results were obtained using non-parametric statistical methods, which are appropriate for limited samples. The second is the fact that participants in the experiments were not randomly selected, since they were Facebook users and in one way or another connected to the experimenters, as experiments were announced through their Facebook accounts.

To conclude, regardless of the validity issues of the present work, the results obtained can be viewed as strong indications towards the direction of using social network data for profiling purposes and visit adaptivity. By using non-parametric statistical methods the researchers tried to eliminate issues of validity emerging from the restricted sample

size, making us view the results as possible manifestations of relations between social network data and cultural heritage visitor experiences.

In general, Experimedia Blue proposed to combine cultural heritage, social networks and people's personalities in a unique way. A new door opens in the exploitation of the available information in social networks for adaptivity purposes. The uses of such practices can be numerous and remain to be studied. Moreover, the users found the approach engaging, entertaining and promising. The popularity of social networks and social network games make it an excellent field for use in cultural heritage. Finally, the present study showed that certain improvements of the two applications (My Museum Story and My Museum Guide) could significantly improve the quality of the visitors' experiences by: predicting cognitive styles more accurately, providing even better recommendations, and combining existing information and individual profiles with group visits and family visits.

Message passing: The Nano-Games Approach

3

Every second of visitors' time matters and needs to be exploited to its best to offer a unique and memorable experience. Time spent in exhibitions is limited to 90 minutes, regardless of their topic or size [12, 21-26], while each exhibit gets only 2 minutes of attention [27, 28]. This gets even more challenging in cases visitors are part of group visits, when they need to "go with the group flow" and "follow the schedule". Due to this time restriction, MIOs need to make sure that visitors are able to find interesting and attractive content which will help towards understanding the MIOs message(s) in the restricted time of their visit. Even in cases where content personalisation is not feasible or practical, MIOs should be able to communicate their fundamental message to their visitors. As [10] mention, it is possible that visitors may learn from an interactive exhibit despite spending only a short duration of time interacting with it.

The previous chapter, Chapter 2 described the use of games for the overall visit-time elongation. However, there are cases when visitors are not aware of the game's existence or do not even have the skills or time to play before and/or after their visit. In such cases, we propose games to be put to use during one's visit in order to enhance their MIO experience. Although this seems like a promising way to go, adopting games in the manner we know, can lead us to the same dead-end as before. This could happen since games in general take time in order for someone to understand the gameplay and become able to play, regardless of whether or not achieving the game's goal. As a result,

a different approach that minimises the total duration of a game play, while focusing on the specific messages a MIO wants to pass to its visitors, is necessary.

Micro-games have been explored by other researchers [74-77] and can offer a solution to the time constrain since they are relatively simple and do not require special skills to play while challenging their players with clearly defined goals reachable within minutes of game-play. In a study [75] that took place at the cities of Prague and Kladno in the Czech Republic, the mean time of user interaction with the game was 20 minutes. When placed in a MIOs exhibition, a single game could be considered as an exhibit. Having in mind the total time spent by visitors in exhibitions, even though it seems promising, one can straightaway realise that if a micro-game approach is adopted, then there is a high risk of visitors not giving the expected attention to the rest of the exhibits, especially if more than one micro-games are in place. In addition to that, the number of visitors tends to increase when the size of MIO is larger, meaning that more visitors will need to spend time interacting with a single exhibit or game. This gets even more difficult when groups of visitors enter the MIO exhibition at the same time. In these cases a solution would be to offer games that enhance the visitors' experience and communicate some fundamental message, but do not require much available time to play and even less time and skills to learn how to play.

To this end, we introduce the concept of nano-games [78]. *We define nano-games as short, easy to master, self–contained games of a single level of difficulty*. In order to keep them short, nano-games have basic and direct rules that stay unaltered throughout the play and challenge players with clearly defined goals reachable within tens of seconds of gameplay. In this way, they allow their users to fully exploit their time, especially when visiting a MIO exhibition.

By exploiting nano-games, visitors can comprehend the main message the MIO wishes to pass in a matter of seconds, with no need of training or experience. Nano-games can be

used either in cases where visitor profiling is possible or even as supplementary material.

3.1 Designing a Nano-Game

When designing a nano-game, one should always keep in mind to make it simple; yet not simplistic. This means straight to the point, clear and concise. The main message(s) that needs to be delivered should be straightforward, presented in a simple way that even someone with no background knowledge would understand. To achieve that, one should focus on a couple of main points the game should promote. Including more information can complex the main message(s), leading to misunderstandings.

Keeping the nano-game simple is not only about its message, but about its entire mindset, including gameplay and controls. In this way, users will be able to soon learn how to use the game, accomplish its goal and ultimately conceive its main message(s). In order for a game to be simple, users should be able to understand the gameplay and its goal in a matter of tens of seconds. The more complex the game is, the longer it will take its users to learn how to play and therefore achieve the game goal. By keeping the gameplay easy and simple, users are able to quickly acquire the primary familiarity with the game [38], heading towards to its mastering.

Keeping a gameplay simple is not however enough in the case of MIOs. There are plenty of simple games that take place in more than one levels, often changing their gameplay and goals from level to level, while keeping them simple. While some may argue that such cases may serve the need to pass multiple messages to the users, one on each level, it is quite time-consuming for their users to adjust and learn over both the gameplay and

maybe even their controls. Nano-games keep it simple as single level games with unaltered gameplay and controls.

Gameplay plays a fundamental role on how simple a game is. However, one should not forget the importance of game controls. Even though the gameplay may be easy and simple, the controls can be hard enough to use, eventually causing users' frustration. Difficulty in game controls can refer to the concept of the control gesture, or to the input/output hardware used to control the game.

In the first case, users are able to handle the controller but the task needed to complete in order to control the game is too complicated to be executed. Also, in many cases the games encompass a variety of tasks that can be executed, meaning that more controlling mechanisms need to be engaged. For example, in a first-person shooter game, users have to control the avatar direction, choose weapon, fire their equipment, run, hide, etc. For every one of the previously mentioned tasks, there is a corresponding control. In order for users to be able to achieve the game's goal, they should be able to learn all game controls, thus making it more complex than a game where a user has to only learn 2 or even 3 controls. Although it is difficult to establish the ideal number of controls, increasing the number of controllers that the user has to learn to operate, may also increase the game's complexity.

In the second case, controllers can be difficult to use or do not respond as their users would expect. Almost always, input controllers such as joysticks and gamepads are used as they are easy to learn, due to their popularity to the public, minimizing the time and effort to learn how to operate them. In the case where such equipment is used, the hardware should be not only robust, able to withstand everyday and heavy use of visitors, but also easy to maintain and minimise the possibility of health risks; especially with the latest developments on the COVID-19. In the case of nano-games the selection of input controllers can be of outmost importance. While the requirements for typical

interactive application like the need for rigidity and ease of maintenance still hold for nano-games, the minimised playtime adds extra requirements in the areas of ease of learn and use. To overcome the above constraints and risks, another option would be to employ sensors and use the visitors' common gestures as a controller for game input. With this approach, users would exploit their biologically primary knowledge to reduce the unnecessary cognitive load and enhance the actual learning [38]. Simple moves such as pointing or kicking towards a direction can be used to control game elements in an effort to minimize the learning period as well as adopt an intuitive way of controlling the game, regardless of ones age or game experience. This alternative makes a noteworthy difference in the total time of game commitment.

If all the above requirements are fulfilled, one could presume that easiness constitutes to the nano-games' shortness. In other words, if a game concludes fast and is easy to learn, users will be able to play within seconds. To achieve that, nano-games should also be easy and simple to play, meaning that users should be able to understand how the game is played and mastered. In addition to that, users should be able to accomplish the nano-game goal fast. In this way, they will not only feel satisfied for their achievement, but also quickly get the full idea behind the nano-game. One should not forget that a nano-game should be both informational and triggering meaning that is should pass the main message(s) in a matter of seconds while provoking its user's interest to further look into more on the subject that the nano-game is about.

A nano-game should also be attractive and engaging in order to have high attraction and holding power as defined by [79-81]. As [82, 83] state, a game has to be challenging in order even for those who have accomplished its goal within seconds, to be able to perform better when playing again. Goals whose attainment is uncertain are essential for a game to be challenging. A game should also be fun and entertaining. However, when designing a nano-game for a MIO exhibition, one should also take into

consideration that the game should be fun and entertaining without upstaging the educational or informative part of it.

In case of nano-games hosted in MIOs, one should first think the target group to which they refer. MIOs tend to be a place where diverse groups gather. However, there are cases where MIOs are targeted mostly to specific groups, as for example art galleries. In such circumstances, the main characteristics of their visitors should be taken into consideration. Age, experience in using games, or even physical status are critical characteristics when designing a nano-game for a MIO exhibition.

Last but not least, it is strongly suggested that nano-games in MIOs are completely independent of human guide presence. Especially in large exhibitions where lots of visitors pass through the exhibits, guides may be unavailable at a specific given time (talking to other visitors) or even following a personalised presentation when presenting an exhibit depending on their experience as guides. As a result, each visitor is presented with a different approach, depending on the guide's profile. In order for every visitor to get the exact same information as the rest, we suggest that the game "presents" itself, with clear-to-follow instructions and information on its topic. As a side effect, the MIO hosting the game would save some costs as well.

All the above requirements should be fulfilled based on the main message(s) a MIO needs to pass to its visitors.

3.2 Focusing on the message to pass

Identifying the message to pass and selecting a suitable metaphor can be a great challenge. To receive these decisions, a team of experts on the MIOs subject and

designers is of the essence. First, experts have to come down to a main message(s) that can be written in a single phrase. A suitable metaphor should be decided, while keeping in mind not to convey dubious or wrong messages. Other, secondary messages can be written down to see if the selected metaphor can cater for them, without obscuring the main message(s).

Early evaluation of the designed prototype, even as a mock up, is of utmost importance in order to avoid unwanted messages. One has to also remember that the selection of graphics can greatly help in that notion. Simple, intuitive graphics have to be selected and unnecessary clutter has to be avoided. New users, who have to learn the game in tens of seconds, need to get information for the task they have to perform, supported in focusing on it. Users should not get distracted with additional, unnecessary information.

3.3 Putting Nano-Games to test

Offering the maximum interactive experience possible in a matter of seconds, while ensuring that every visitor leaves with an understanding of what the venue wished to communicate is quite challenging. Time and background knowledge constraints make it difficult to come up with a feasible approach. However, nano-games seem to provide a light in the darkness.

To put nano-games to test, an experiment as well as an evaluation was essential. To make sure that the nano-game approach would endure loads of users in a short period of time, we sought for a popular MIO that attracts a variety of visitors, regardless of their background knowledge.

3.3.1 CERN

The European Center for Nuclear Research, called CERN [84], is an international research facility of great importance. CERN is located on the border of Switzerland and France, currently being the largest particle physics laboratory in the world. Operating a network of the world's biggest and most complex machines, CERN's main focus is the study of the smallest constituents of matter – fundamental particles. Particles are the minute fragments from which all matter in universe is made of. In order to be able to study them and, consequently, unravel the basic laws of nature, these minute particles of matter are being accelerated to a fraction under the speed of light and then forced to collide with a rate of more than 1 billion times per second [85].

CERN operates several accelerators and one decelerator in a building complex that straddles the Swiss and French border. Accelerators are devices accelerating particles, such as protons and electrons, at very high speeds and energies while decelerators are devices slowing down particles.

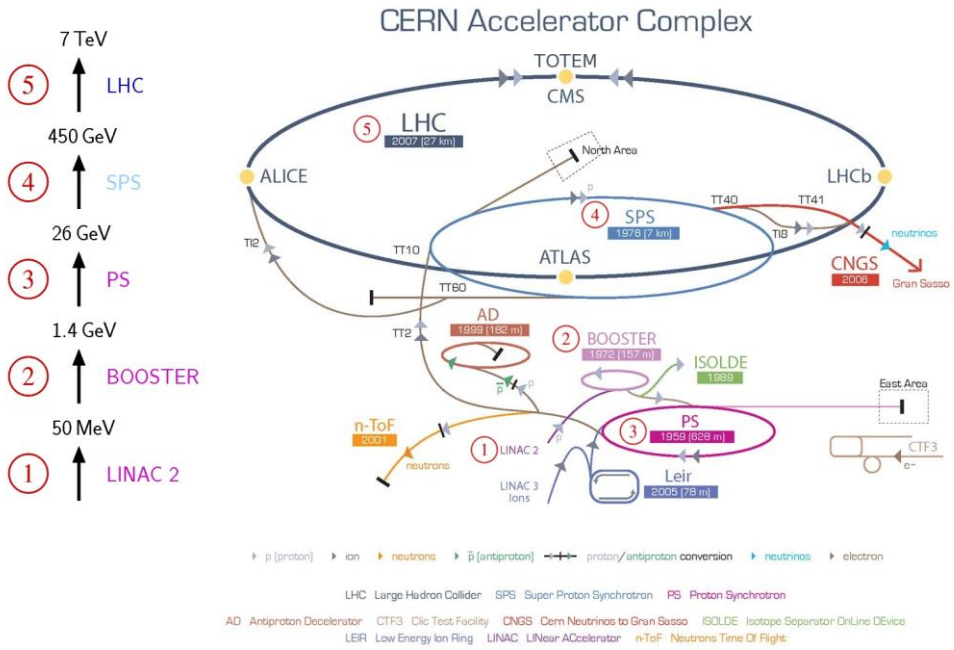


Figure 3-1. The CERN Accelerator Complex Illustration.

Everything starts from a simple bottle of hydrogen gas. Hydrogen atoms get stripped from their orbiting electrons in order to yield protons. Then, these protons are injected into a sequence of machines with increasingly higher energies. Figure 3-1 shows CERN's sequence of accelerators. Sets of particle bunches moving in the same direction at the same time, called beams, are injected from one machine into the next one, getting all the more speed and energy until they reach a speed close to the speed of light (99.9999991%). The last machine in this sequence is the Large Hadron Collider (LHC) accelerating particle beams up to the record energy of 7TeV.

The Large Hadron Collider (LHC) is a 27km long ring located in a depth of 100 meters below the face of earth and consisting of superconducting magnets and a series of accelerators. The LHC is the world's largest and most powerful particle accelerator being operated nowadays in an effort to unravel the mysteries of the Universe. Inside the LHC, beams are travelling in opposite directions and are forced to collide in determined places where humongous machines, called detectors, have been constructed to study what new particles are formed from the high energy. These places are called experiments.

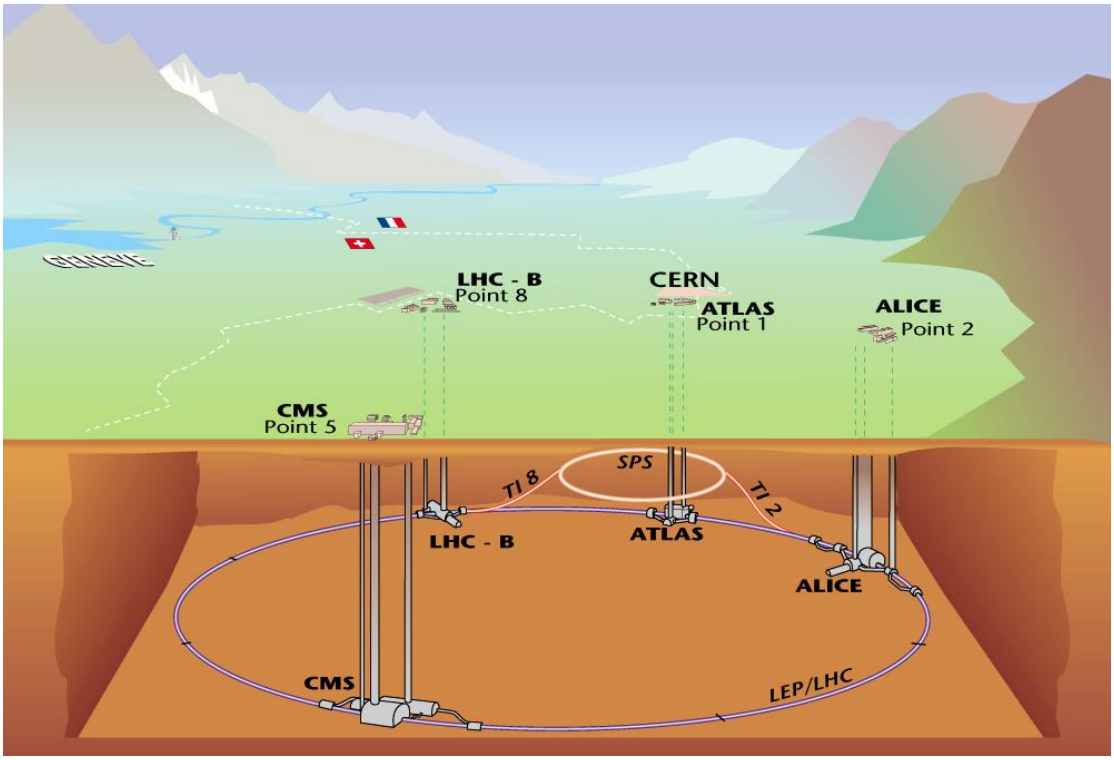


Figure 3-2. Overall view of the LHC experiments.

Seven experiments sit underground in huge caverns on the LHC ring; ALICE, ATLAS, CMS, LHCb, LHCf, MoEDAL and TOTEM. Figure 3-2 shows the locations of the experiments on the LHC ring. Each of these experiments has detectors, machines gathering information, such as speed, mass and charge, regarding the beam collisions happening inside them. This information gets transferred the CERN Data Centre, where each collision gets digitally reconstructed and, compared to actual collisions.

Having a great history in the field of particle physics, CERN has attracted increasing interest during the past few decades (Travellers' Choice for 2020 as voted in Tripadvisor [86]) from scholars, researchers and tourists. As a matter of fact, more than 110,000 people visit CERN per year [87], a big portion of whom are under-informed, trying to find out more information about the organisation and figure out what its purpose is to the community. In order to provide visitors with the information they are seeking for, various visit points as well as a permanent museum exhibition called Microcosm, are available to the public.

While the various visit points are spread around CERN, Microcosm is located in one of the two main sites of CERN, Meyrin, Switzerland. The museum provides its visitors with an introduction to CERN and particle physics. Due to the lack of background of most of its visitors, CERN tries to provide simple and easy to understand content using different means. Images, videos, interactive objects and applications are used in an effort to present CERN's purpose simplified, without losing neither the significance nor the deeper meaning of organisation's existence.

Figure 3-3. CERN's museum, Microcosm.

Despite Microcosm being open to the public Monday through Saturday, the number of people desiring to visit CERN cannot solemnly be satisfied by its main exhibition, Microcosm. Hence, there are cases were visits have to be scheduled even one year in advance, if a time slot is available. In addition, not everyone can travel to CERN and have the opportunity to explore it. Long distance and insufficient financial capability can be two of the most common reasons for people to not be able to reach CERN. Early efforts to soothe this problem and give everyone the opportunity to experience CERN included

flash-based browser games on how the Large Hadron Collider, CERN's largest and most famous particle accelerator, operates. However, these games proved to be not sufficient enough, raising the need for more interactive and informative media.

To overcome this problem, CERN has come up with a travelling exhibition providing its visitors with information about CERN and its scope. Due to its compact size, the travelling exhibition is an effort to provide its visitors with the information they seek for, without having to physically travel to CERN. The travelling exhibition exploits all possible means of presenting information, including images, videos, mockups and games. Part of the travelling exhibition is the LHC Interactive Tunnel, or else LIT, an immersive, interactive space implementing the CERN experience using everyday life metaphors. LIT was developed by CERN Media Lab [88], a team who designs and implements systems, software and content for Science Visualization and Communication in order to support CERN's education programmes. The concept of LIT was to be a mobile interactive space, explaining with an easy to understand way CERN's purpose and contribution to society. However, throughout the years, LIT has also managed to be part of CERN's permanent exhibition.

LIT hosted two interactive games that make visitors experience physics, instead of reading or hearing about it using controversial ways. To play the games, users need to use their body parts for the gameplay to proceed.

3.3.2 LHC Interactive Tunnel (LIT)

3.3.2.1 LIT Architecture

The architecture of LIT is quite simple. The earliest version, sized six meters long, six meters wide and three meters tall, providing a user area of six meters long and two and a half meters wide. Figure 3-4 is a model of the original LIT, consisting of (a) seven

projectors perfectly aligned, having five in the back projecting on a projector screen (Figure 3-2. b and **Figure 3-2. c**) and two on the ceiling to project on the floor, (b) four Kinect [41] sensors, positioned as illustrated in the image 1, (c) an 5.1 audio system, (d) two computers communicating through (e) local network and (f) a tablet to control the system. The architecture of the system allowed the user to interact with her environment without the use of any kind of equipment such as joysticks, controllers, keyboards, etc. The users could use their body movement in order to trigger events and interact with the games.

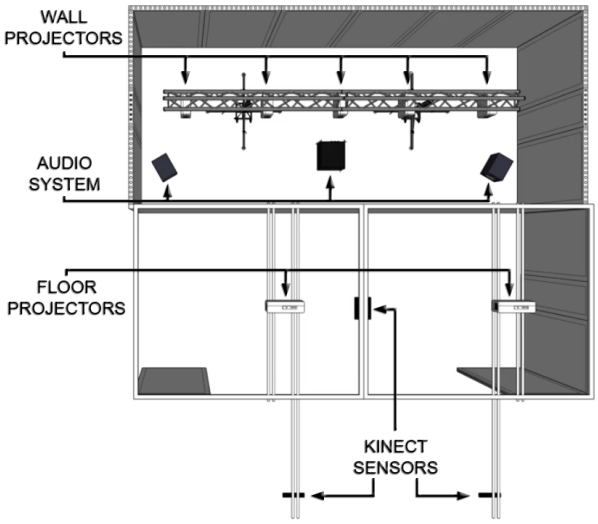


Figure 3-2. a. LIT Architecture top view.

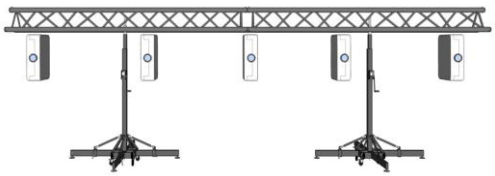


Figure 3-2. b. LIT Backstage Architecture with five projectors.

Figure 3-2. c. LIT Backstage Architecture includes five projectors and an audio system.

Figure 3-4. LIT Architecture.

The second and current version of the LIT, is more compact as it sizes six meters long, two and a half meters wide and 3 meters tall. Projector screen was replaced by a video wall of six 55" full HD screens, while the projectors remaining are only two, positioned now below the video wall.

3.3.2.2 LIT Software

As mentioned above, LIT offers two educational games to its users as well as some introductory video material. The video material focuses on information regarding where CERN is located, where its accelerators and experiments lay, where collisions happen, and what is inside a dipole and it works. The educational games, called "Proton Football" and "Higgnite", focus on information on how an experiment works and the Higgs field.

Proton Football – Become a particle accelerator yourself!

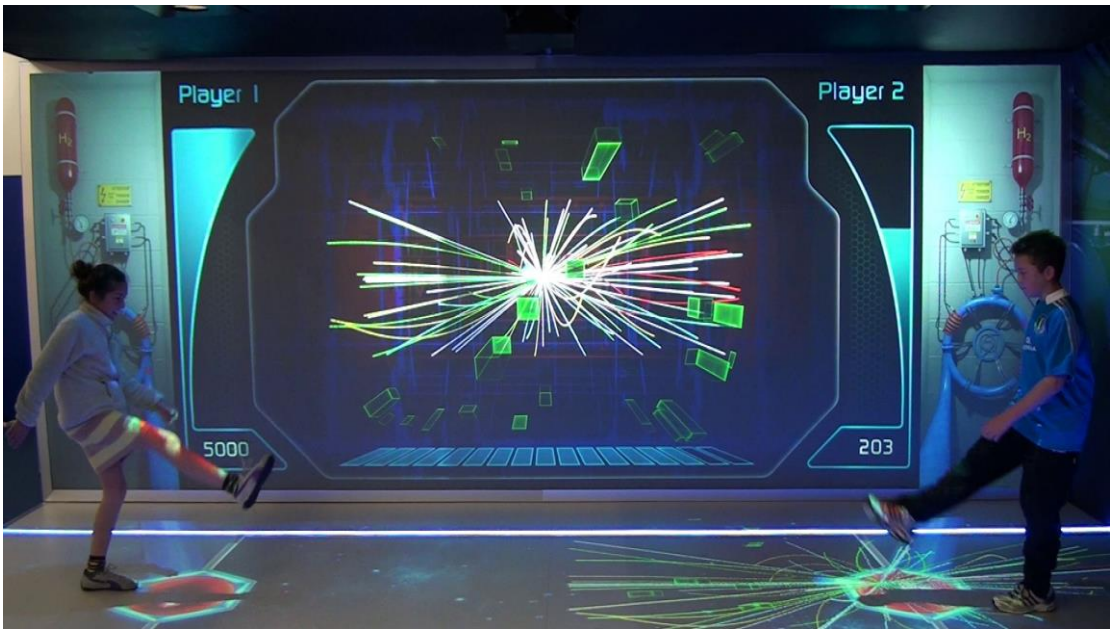


Figure 3-5. Proton Football Interface.

Proton Football is a two-player game giving its users the opportunity to become a particle accelerator themselves by "kicking" iconic protons. The game aims in informing visitors on how an experiment works. To achieve that, the architecture of one of CERN's experiments (ATLAS) is shown on the video wall while both players are given iconic protons, projected on the floor, to which they have to give energy and make them collide in order for the experiment to operate and produce data. Figure 3-5 shows the Proton Football interface. Two protons are projected on the floor, one on each side for each

player, waiting to be kicked by their players. The protons start from a Hydrogen bottle, get injected in the LHC and then are positioned in front of each player. To accelerate a proton, a user has to virtually kick it. To do so, the player has to do a physical strike to the virtual proton projected on the floor using one of her feet. To achieve a collision, the player must also aim for her playmate's proton. The more intense the kicks the players make, the more energy they give to their protons. In the event of a collision, the tracks of the new particles generated from the collision will be shown in both the floor and the wall sides. Tracks are distinguished by colour to achieve a visual categorization of the tracks depending on the energy of the particles that created them.

Proton Football's metaphor relates the LHC experiment to kicking two balls and make them collide in the maximum energy possible. By doing so, players are presented in everyday, simple examples how a CERN experiment works. Furthermore, they experience that "It is very difficult to make two protons collide", which is the game's main message, since careful coordination and estimation is needed to reach the game goal.

Proton Football also provides a variety of triggers for questions from the visitors. Questions about what an experiment is and how it works, where do protons come from, what a quark is, what the outcome is from these experiments, how is CERN related to the Big Bang, are only a handful of questions visitors usually come up with just by looking at the user interface of the Proton Football game. While being simple to play, Proton Football deals with complex issues, giving a fun and simple way for uninformed visitors to have a basic idea of what CERN is and does.

Higgnite – Experiencing the Higgs Field

Higgnite is the second game hosted by LIT. Offering an artistic representation on how a player would be projected in the universe as a particle before and after the Big Bang,

Higgnite gives a simple way to understand not only what the Higgs field is but also its impact in our lives. Figure 3-6 shows Higgnite user interface.

Figure 3-6. Higgnite user interface.

Contrary to the Proton Football game, Higgnite actions take mostly place on the wall side. The video wall is divided into two sections, with the left one being without the Higgs field and the right one with it. On the left side where the Higgs field is not enabled, players are able to move freely in space and their projection will follow them immediately, without any delay. However, as soon as they pass the barrier and move to the right side where the Higgs field is enabled, they "gain mass" and they experience all the changes that happen because of that. Firstly, they realise that there is a sparkle around their projection, which represents the interaction with the environment. Secondly, they cannot move freely anymore as when there is a delay in the movement of

their projection as well as a trail left behind which symbolises inertia. Finally, there is a change in the sound, indicating these changes in the interaction with the environment.

The experience of the Higgs field through playing Higgnite triggers a variety of questions, starting from the Higgs field and the Higgs boson to cosmic rays, black holes, dark matter, and extra dimensions.

3.4 Our Nano-Game Genesis

Throughout the years, numerous approaches have been made to inform the public about serious health issues, even fatal, and their possible treatment procedure, most them focusing on patient treatment, disease prevention, and health promotion [89-92]. However, only a handful approaches deal with life-threatening, non-contagious diseases such as cancer.

[93] present a game prototype, called Cytarius, developed to illustrate cancer treatment in an effort to inform mainly children and teenagers. During its gameplay, users are dealing with different types of cancer per level and are provided with treatment options to win the levels. Difficulty increases as its users advance through the game. Evaluation asked for users to play the game for 15 minutes and showed that participants enjoyed it. However, constraints such as interruptions and non-quiet environment seemed to affect participants' engagement.

Re-Mission2 [94] is also a multilevel game played either on a PC or mobile phone, aiming to provide cancer support to their players. By using a number of different weapons, players fight cancer by controlling a robot located within a body. To move to the next level, users have to complete successfully one level. Re-mission2 offers its

players a sense of power and control as well as treatment engagement. Evaluation [95] requested participants an hour of gameplay per week, as well as two follow-ups during the next three months.

Even though promising results have been reported in the above-mentioned evaluations, both games require time and engagement from their players. As mentioned before, when visiting MIOs, visitors have limited time available and their re-visit is not certain. Also, visitors might not be aware of a game's existence before their visit or not have the skills or engagement to play the game outside their visit. Nano-games is a promising approach for MIOs that wish to communicate message(s) related to life-threatening, non-contagious diseases such as cancer to their visitors.

CERN is mostly known about its contribution to the physics field. Yet, the organisation has a fundamental role in determinant discoveries throughout the years, with only a few people actually knowing that CERN was the birthplace of fundamental theories and technologies. A vast majority of the technologies find actual application in our every-day lives, from medical diagnosis and therapy to computer chip manufacture ideas, proving CERN's crucial role in the progression of various fields. Revolutionary technologies as such the World Wide Web and the Grid in computing and X-Rays, PET and MRI scans in medicine are only a handful of representative examples [96, 97].

As already mentioned above, LIT hosted two games, informing visitors about how CERN operates and the Higgs boson, as well as some video material on general information about CERN. One of these interactive games was Proton Football, developed in 2011 in an effort to explain to its users in a simple way how a CERN experiment works. Proton Football was an early attempt at reducing the gameplay time, while conveying a clear message. Higgnite was the second interactive game informing its users about the Higgs field.

One of CERN'S major contributions is associated with innovative cancer treatment methods. To this end, it was decided to design and implement a nano-game, highlighting CERN's contribution and informing visitors about cancer, hadron therapy and CERN's role in this new procedure. The new nano-game was called HEAL (Hadron Emission Applications Laboratory) and is now part of both Microcosm and LIT travelling exhibitions.

Additionally, CERN is a large and popular organisation of high importance attracting all the more visitors [86, 87]. As a result, CERN seems to be the most suitable testbed to evaluate whether nano-games can meet the demanding requirements of a MIO regardless of their size or topic, while providing a high quality of experience for their users.

Nano Game proof of concept: The “HEAL” Application

4

HEAL [78] is a novel, interactive game aiming to inform it’s players, inter alia, on what is hadron therapy and how it works. The name of the game, HEAL, is an acronym formed from the words “**H**adron **E**mission **A**pplications **L**aboratory”, carrying both an underlying information message and an optimistic feeling for this medical therapy. The gameplay simulates how hadron therapy works, giving information on the entire procedure, from the point when the beam starts to the point when the beam reaches its destination inside the human body.

The HEAL game, apart from offering insights into a new cancer therapy, provides answers to a number of basic questions including what hadron therapy is and how it works, why it may be preferable to other treatments, what is the connection between CERN, medicine, and in consequence our everyday life.

While playing the game, the user is located inside a medical laboratory as perceived by the equipment depicted at the graphics and is challenged to face a tumour. Figure 4-1 shows the HEAL interface. Cancer cells (tumour), as well as some complementary information related to the gameplay, are shown on the wall side of LIT. A visualisation of the human head and brain, including details of cells to help players understand the difficulty of the task and to enhance the user experience. To destroy of the tumour, the user is encouraged to use hadron therapy. A particle accelerator, projected on the floor, can be used to accelerate hadrons and inject them to the tumour in order to defuse it.

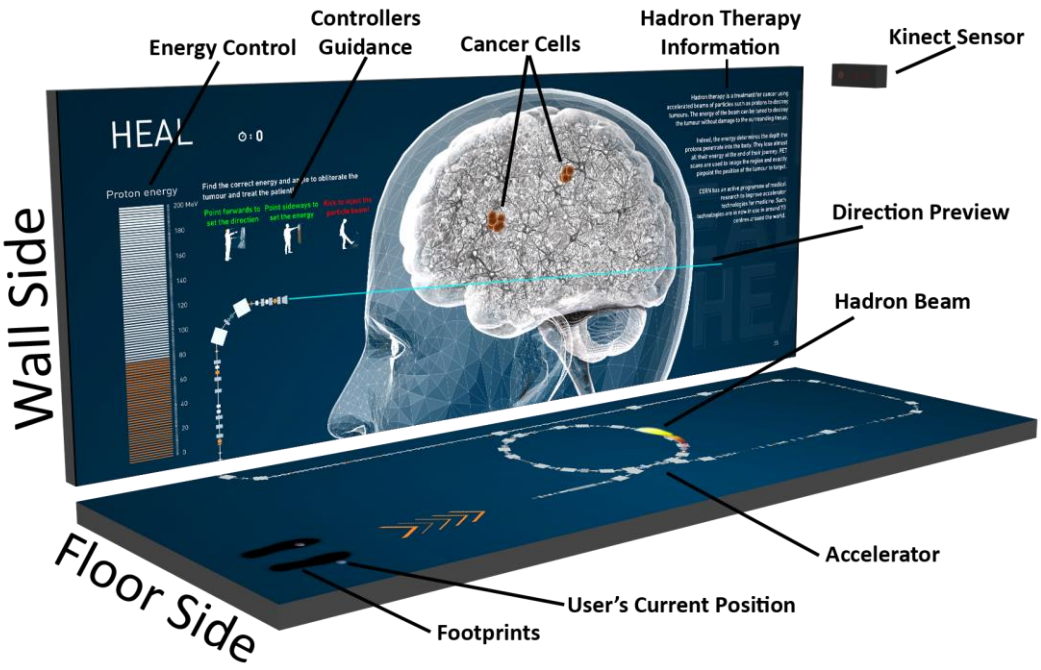


Figure 4-1. The HEAL interface.

The basic interaction of users with the system is the implementation of physical actions in order to adjust and set parameters as well as conduct the treatment. To operate the system, the player has first to set the energy and the direction in which the hadron beam is going to be injected, and then fire the beam in order to get accelerated and sent to the specific cancer cells as defined by the selected energy and direction. To select the desired energy, the user has to extend her/his hand in parallel with her/his body and move it on the vertical axis, as shown in Figure 4-2. The higher the player's hand is, the more energy s/he shall select. Direction can be set in a similar way, by extending one's hand perpendicularly to her body, as shown in Figure 4-3, and changing the direction, again, by moving it vertically. After successfully setting both the energy and the direction in which the hadron beam is going to be injected, the player can give a boost to the hadron beam by kicking the hadron beam illustrated on the floor.

Figure 4-2. HEAL in Microcosm. User is adjusting the energy to which the hadron beam will be emitted to the humanoid's brain.

Figure 4-3. HEAL in Microcosm. User is adjusting the direction to which the hadron beam will be emitted to the humanoid's brain.

The overall scope of this initiative was focused around passing the following messages to players:

- Understanding what Hadron Therapy is and how it works.
- Understanding that serious health-diseases can be treatable.
- Highlighting CERN's involvement in other research fields, apart from physics and computer science.
- Highlighting CERN's impact on our everyday lives through technological achievements.

To this end, the success of this initiative has to assessed primarily to the extent of players understanding one or more of the previously mentioned messages and secondarily to the mental and emotional impact a message related to sensitive health issues has on the players.

4.1 Acquiring the Particle Therapy Basics

Cancer is "a broad term for a class of diseases characterised by abnormal cells that grow and invade healthy cells in the body" [98]. Cancer is one of the most widespread diseases worldwide with more than 8 million deaths in 2016. According to the World Health Organisation (WHO) report [99] cancer is the second major cause of death in developed countries.

4.1.1 Treating Cancer with Radiation

Radiation therapy is a cancer treatment using high doses of radiation (similar to X-Rays) to destroy cancer cells and, as a result, shrink tumours. *Radiation* is the "emission or

transmission of energy in the form of waves or particles through space or through a material medium" [100]. By irradiating cancer cells and severely damaging their DNA, their inactivation will come inevitably since they fail to repair their damaged DNA ([101]). Radiation therapy has been the cornerstone of cancer treatment since it combines the three "C"s: **C**ure of cancer, **C**ost effectiveness and **C**onservative treatment ([102]). While being excessively used due to the three "C"s, radiation therapy has serious side effects as for example the affection of healthy normal cells located near the tumour.

Radiation therapy has two main types depending on the position of the radiation source: *Internal Radiation Therapy* and *External Beam Radiation Therapy*. In the Internal Radiation Therapy the source of radiation, either solid or liquid, is put inside the patient's body.

The *External Beam Radiation Therapy* is a non-invasive type of cancer treatment. The tumour is being irradiated from outside the body. In order to achieve that high-energy X-Ray machines are used to direct radiation to the tumour. External Beam Radiation Therapy falls into two categories: *Conventional Radiation Therapy*, and *Particle Radiation Therapy*. While the first category uses photon or electron beams, the latter one uses neutrons, proton and heavier ions, such as carbon, to achieve a more precise and efficient treatment with the least possible side effects [103, 104]. For the sake of accuracy, Table 4-1 provides a list of advantages Particle Radiation Therapy has over Conventional Radiation Therapy.

Although photons can also be considered as particles, photon therapy is not considered as Particle Radiation Therapy. Additionally, electron therapy is generally put into its own category. Therefore, Particle Radiation Therapy is more correctly referred to as Hadron Therapy, a cancer treatment using particles made of quarks.

Table 4-1. Advantages of Particle over Conventional Radiation Therapy

Conventional Radiation Therapy	Particle Radiation Therapy
Physical dose high near surface	Dose highest at Bragg Peak
DNA damage easily repaired	DNA damage not repaired
Biological effect is lower	Biological effect is high
Need of oxygen	No need of oxygen
Effect not localised	Effect is localised

4.1.2 Particle Radiation Therapy

Particle Radiation Therapy, or else *Hadron Therapy*, is a radiation therapy using strongly interacting particles, called hadrons, as for example neutrons, protons, pions and ions (alpha, carbon and neon) [105-107]. Particle Radiation Therapy requires particle accelerators, which cause the particles to accelerate so their energy is sufficient to reach the distal edge of a tumour.

The strength of hadron therapy resides in the fact of exploiting the properties of the *Bragg peak*, a point of increased concentration as radiation moves through a patient's tissue. Figure 4-4 shows the curves representing the relative doses of protons and carbon ions comparing to photons (X-rays). While photons are highly penetrating and deliver a dose throughout any volume of tissue irradiated, protons and carbon ions deliver their maximum dose at a precise depth.

Photons deliver most of their dose 0.5 to 3 cm from the patient's skin, depending on the energy they were initially given. They then gradually lose their energy until they reach the target. As tumours are almost always located in-depth, photons actively interact with outer healthy cells and drop only a small remaining dose of ionizing radiation on the deeper diseased cells. Moreover, as they are not all stopped by human tissue, they leave the patient's body and continue to emit radiation (exit dose).

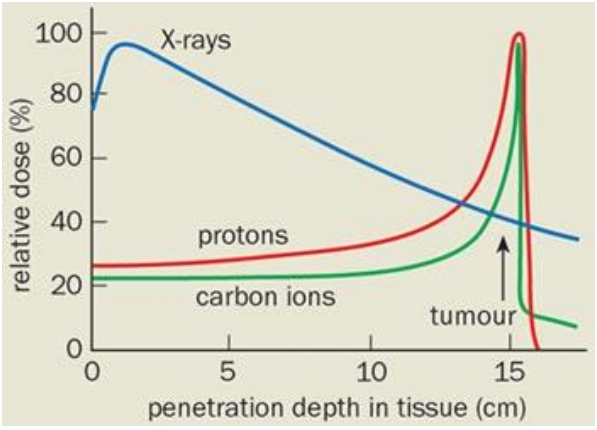


Figure 4-4. Percentage on-axis depth-dose (PDD) curves of different types of radiation.

On the contrary, protons are very fast when entering the patient's body, depositing only a small dose on their way. The relative dose increases very gradually and mainly exponentially as hadrons penetrate tissue, depositing almost all of their energy at the very end of their path in a sharp peak called the Bragg Peak. Immediately after their burst of energy, hadrons completely stop to irradiate. This characteristic enables precise definition of the region to be irradiated. Thus the tumour can be irradiated with less damage to healthy tissue that is the case using Conventional Radiation Therapy [108, 109]. The depth in which they can penetrate, and as a result deposit most of their energy, can easily be controlled by determining the amount of energy they are given.

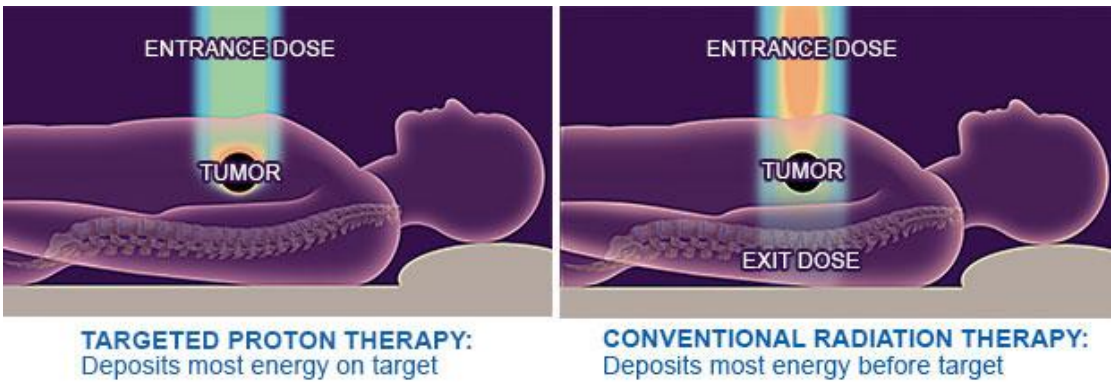


Figure 4-5. A comparison of radiation delivered with conventional (high energy X-rays) radiation therapy versus proton therapy. By contrast, proton therapy has a much lower entrance dose and no exit dose.

4.1.3 From water to Proton Therapy Treatment

Hadron therapy centres are humongous with some of them having the length of a football field and the height of a three-story building. A particle accelerator is the heart of every hadron therapy centre, with most of them being cyclotrons as protons are more widely used in Particle Therapy Treatment.

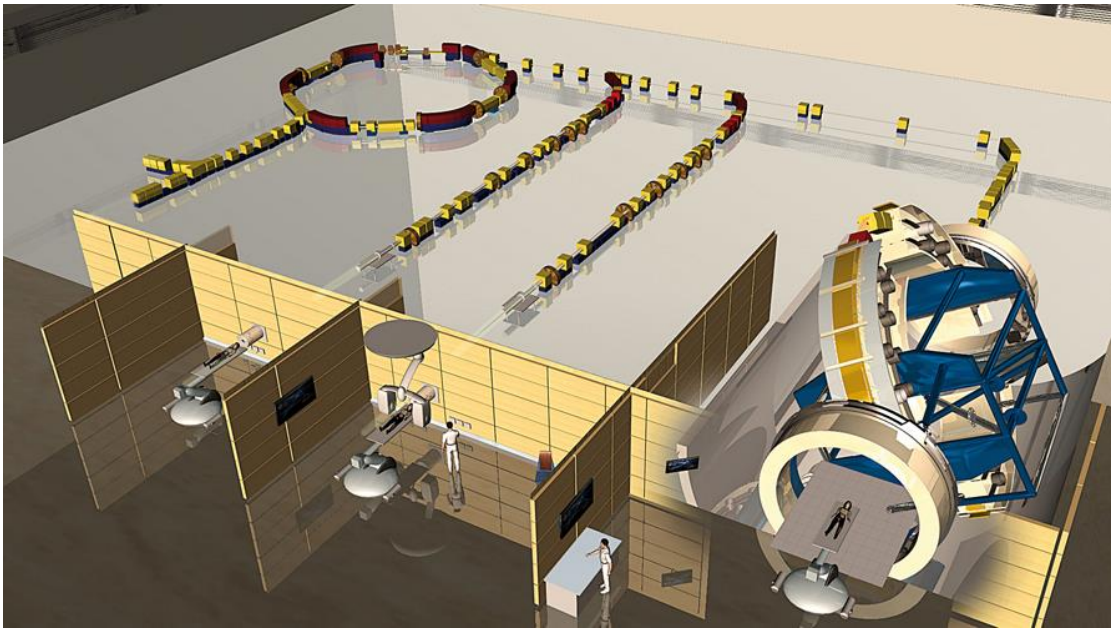


Figure 4-6. Clinical facility in Heidelberg.

It all begins with electrolysis, a procedure where hydrogen atoms are separated from water. Then a positively charged proton is extracted from each hydrogen atom and injected into the cyclotron. Using electromagnetic fields, the cyclotron accelerates the protons up to 2/3 the speed of light, all within fractions of a second.

The proton beam is then taken from the cyclotron and passed through an energy selection system, which makes the beam's energy variable for use in each of the treatment rooms served by this beam. This allows each room to use the energy needed for that patient.

The beam transport system then transports the accelerated protons through the beam transport line into each treatment room. Electromagnets are positioned along the line to route the proton beams around corners and into each treatment room.

Large, sphere shaped structures called gantries are located in some treatment rooms in order to guide the proton beam from the beam transport system to the beam delivery nozzle. The gantry allows the beam to spin 360 degrees around the patient. A fixed-beam treatment room does not require the gantry because the beam does not move around the patient. Instead of moving the beam around the patient with a huge gantry, the beam comes out of a pipe stuck in the wall and the patient is moved around the fixed beam.

Figure 4-7. Proton Therapy system.

4.2 Game Development Process

4.2.1 Development approach

While the development approach is based on [110], the very first step was to decide on the message or messages the game itself had to pass to the visitors. This stage is crucial, as a nano-game spends very little for the actual gameplay and has thus limited opportunities to pass a small number of messages to the player. Therefore, prior to deciding on the game mechanics, the designer has to define one or more concrete messages that will be communicated to the player, while playing the game. The limited playtime also limits the number of messages that can successfully be passed to the user. The designer has to make sure that the message(s) are not ambiguous or misinterpreted.

4.2.2 Deciding on the message

As previously noted the main challenge of developing a nano-game is identifying the message and selecting a suitable metaphor to help pass the message across. To this end, for the development of the heal game a team of experts on the subject and designers was formed. First, experts have to come down to a fundamental message that can be written in a single phrase. A first guideline is to start designing only when this message is identified and agreed upon. In the case of HEAL game, the phrase to pass was “It takes careful planning to hit a tumour target”. Other, secondary messages can be written down to see if the selected metaphor can cater for them, without obscuring the main message. Secondary messages for HEAL game, as also described in paragraph 4.1.2 , were: “The new therapy can be very efficient” and “A particle accelerator is used for cancer treatment”.

The second major challenge is to identify a suitable metaphor. When deciding on the metaphor to be used, one should keep in mind both the MDA framework and the nano-game's nature. As nano-games last only tens of seconds, game mechanics should be kept simple and minimum in order to be easy to learn, while keeping the game challenge to a suitable level. For this nano-game a full body gesture-based environment is being used. The basic guideline calls for metaphors based on universally understood and accepted gestures. Before selecting the metaphor to go, one should keep in mind that it has to be programmatically implemented and technology has its limits. As described in paragraph 4.1.2 in Proton Therapy machines are used to **direct** radiation to the tumour from outside the body. In the case of HEAL game, the metaphor was initially that of an archer. But, the metaphor's vagueness and technical difficulties changed the metaphor to that of "point to an object". Also, in Proton Therapy, the equipment has to be configured to use the appropriate dose (energy). Since protons deposit almost all of their energy at the very end of their path (Bragg Peak), one should **adjust** the amount of energy given as it determines the depth in which protons penetrate. Finally, protons are **accelerated** to the selected energy at the selected direction, and emitted to the tumour target. Since "direct", "adjust" and "accelerate" are the three keywords that describe the process one should follow to **operate a Proton Therapy accelerator** and **destroy a tumour target** (Dynamics), it was decided that these three keywords formulate the basic actions (Mechanics) for HEAL. In HEAL users need to point to two different directions, with each one controlling different game elements. Users have to stand on the footprints at a predefined place (Figure 4-1). To select the beam direction, users have to point to the tumour, while to select the beam energy users have to point to the energy bar on the "Wall" side. To adjust the direction and/or the energy to the desired one, users need to move their corresponding hand up (for higher) or down (for lower). After adjusting both controls, users need to physically kick a virtual proton in order to be accelerated and emitted with the selected energy to the selected direction. Even though HEAL is easy to

learn to play, hitting a tumour target takes careful planning. Users are **challenged** (**A**esthetics) to precisely direct and adjust the available controllers in order to be able to destroy the tumour target and master the game,

Another major challenge is to select mechanics that do not to convey dubious or wrong messages. For example, while considering whether HEAL game should be a single or two-player game and having implemented the popular Proton football LIT game, the first notion was to re-use the football metaphor. But, that would probably mislead players into thinking that the tumor was being attacked from multiple sources. To avoid issues derived from the two-player game, it was decided to adopt a single player type of game. However, in case of a two-player configuration, the tasks would have to be redistributed to allow two players to play. Again, the guideline calls for early evaluation of the designed prototype, even as a mock up, to avoid unwanted messages. One has to remember that the selection of graphics can greatly help in that. Simple, intuitive graphics have to be selected and unnecessary clutter has to be avoided. A new user, who has to learn the game in tens of seconds, has to get information for the task that needs to be performed, supported in focusing on it. Users should not get distracted with additional information.

4.2.3 General Principles

HEAL intended to provide an informative environment for CERN visitors regardless of their physics or medicine background. Thus, it was important to design a game activity that would match the visitors' interests, while at the same time motivates them to explore underlying physics and medical concepts embedded in the game. Several issues were considered in the design of the game activity:

To start with, HEAL was designed as an interactive game with an interface suitable for any visitor, regardless of their age and previous game experience. Visitors were able to

interact with the game having zero experience with Kinect [41] sensors, just with the rise of a hand or foot, body movements that people develop from a very young age [38].

As an experience enhancer game, HEAL should also support the understanding of the informative content and stimulate reflection about the physics and medical concepts. Thus, it was designed to prevent visitors from only paying attention to the entertainment elements in the game, while ignoring the underlying concepts. In our case, this is due to the game metaphor itself, as the gameplay represents the main message the MIO is trying to pass to its visitors. For HEAL, users need to (a) aim for the cancer cells (b) using the correct energy, which are the two variables a user has to set in order to achieve the game goal.

While designing HEAL, one should not forget its gaming nature. The game should have a goal to achieve in order to create a sense of mission to its users, while carefully balancing the level of challenge and frustration. As [50] mentioned, a game should be challenging, motivating and winnable to all players. To achieve that, users have to adjust precisely the amount of energy needed and direction to irradiate the tumour.

In addition to the above, users should need to continually increase and refine their understanding of the embedded physics and medical content, in order to both keep their interest and deepen their understanding on the content. In HEAL, users have to speculate the exact amount of energy needed in order for hadrons to stop exactly were the cancer cells are located. In case the energy is less or much more than the requested one, the cancer cells will stay intact and users would have to readjust it in order to destroy them.

Finally, the game should provide adaptive feedback and rewards. Feedback helps players understand their progress and evaluate their choices and decisions while rewards such as scoring can be effective in increasing users' motivation. In HEAL, the

time taken by a player to destroy the cancer cells located in the patient's brain is measured. As a result, players can compete not only against cancer but also against each other.

4.2.4 Assumptions

Before designing the game, a set of assumptions were made. To start with, we assumed that:

- Users have went through the previous Microcosm exhibits, or played the "Proton Football" LHC Interactive Tunnel game. With this assumption, we make sure that users have the needed background in physics before playing HEAL.
- Users have no more than 5 minutes to spare for playing the game. Even in the case when they do, the game should be simple enough to not keep them more than 5 minutes in order for more visitors to be able to experience the game.
- Users can physically move at least one of their hands and feet.

4.2.5 Specifications

4.2.5.1 Gameplay Specifications

The number of players a game can be a crucial factor on passing the correct message to the game's users. Especially in educational or experience enhancer games that have either an educational or informative purpose, there is a high risk that users get a wrong perception of the presented concept.

4.2.5.2 Functional Specifications

HEAL's functionality is entirely based on the body movements of a user. In order to achieve it, a sensor is used in order to capture this information and send them to the

application. This information should reflect the position of the user joints of a user being inside the interactive space.

4.2.5.3 User Interface Specifications

HEAL's graphical interface should be designed having usability as a top priority. The game should be presented and organised in a manner that is both visually appealing and easy-to-use by its users. The layout and the user interface of the game should be simple enough for users to take no time in learning its features and using its controllers with little, none if possible, difficulty. In order to achieve the highest usability possible, we need to make sure that the game is providing a list of elements and is following a list of design rules as described in [111]. Colours should be carefully selected to be friendly to colour-blind people. Contrast in brightness and saturation between texts and backgrounds is suggested while the combination of colours of the same brightness but different hue should be avoided. Dark text over bright backgrounds (or vice versa) is advised, contrary to red characters on green backgrounds which is unreadable for colour-blind people. Text fonts should also be easy to read.

First of all users have to know «where they are». In order to provide this information, the background of the «Wall» side of the game simulates the inside of an infected by cancer human head. Details such as the outline of a brain, the nerves complex and cancer cell masses make the interface more vivid to the users. While trying to give a lucid notion with the mentioned details, HEAL engages a humanoid as the subject for treatment in order to eliminate the possible negative emotions either while treating the patient or when failing to adjust correctly the energy or direction parameters. On the «Floor» side, the user is located in a Hadron therapy laboratory, having available a particle accelerator to be used for the treatment. The background should be kept simple in order for the different components of the accelerator to stand out. A pipe coming out

from the accelerator is passing from the «Floor» to the «Wall» side, injecting the beam when available and connecting both sides of the gameplay.

Then, users should know «what they can do». As soon as a player enters the game area, indicated by two foot imprints, a set of instructions should be shown on the «Wall» side explaining the different controllers and the goal of the game. Instructions should be clear and descriptive, followed by images for more clarity.

Knowing «what they are doing» or «what will happen» is really important throughout the game in order for players not to feel lost in the gameplay. Descriptive captions should be available close to every indicator and controller of the game while text indicating the status of the game controllers should also be visible. All the text information should be readable, yet space-efficient. Apart from having informative and descriptive text, HEAL should also provide its users with interactive controllers indicating the values to be set in the game controllers. In that way, users can set their values and estimate what will happen, before the actual event happens. This will be explained further in a chapter to follow.

Finally, users need to know «where have they have been». In HEAL's case, users are provided with information related to their last set values. Greyed out indicators show the game's last controller values, allowing them to adjust better their newly input values.

For graphically designing all the above elements we took into consideration practices being applied in video games. A bar having an adjustable filling is used to simulate the energy the user has entered to the system. The more energy the user sets, the more full the bar is, and vice versa. Regarding direction, since we are talking about a vector showing the direction the hadron beam is to follow, the use of a line was chosen. As far as the visualization of the tumour is concerned, gloomy textures, dark colours and

movement will be applied in order to be quite clear to the users that these elements are "malicious" and need to be "destroyed".

4.2.5.4 Performance Specifications

As far as performance is concerned, memory and processing power are worth considering factors as they could affect the game performance. Noticeable delays between the actions of players and the reaction of the game can cause serious problems while playing the game. In order for the game to perform in the best possible way, we need to make sure that the source code is highly efficient, thereby using less system memory and resources, thus minimizing the possibility of lag occurring and being instantly responsive.

A quite representative measure for the game performance is the frame rate of the game. Most games seek to maintain at least 30 frames per second since below this threshold the human eye can start seeing imperfections in the animations or the motions of objects as the move. We can therefore argue that in case the game's frame rate drops more than 30 frames per second, then its performance has become too slow. In order to reduce such likelihood of such event to occur, we need to ensure that (a) the processing power is enough, (b) the memory usage is minimum, (c) the memory allocation is done correctly, (d) the number of functions being executed every single frame and (e) the size of data being sent and received through the network is minimized and (f) having both sides of the game («Wall» and «Floor» sides) synchronized.

4.2.6 Architecture

4.2.6.1 Hardware Architecture

HEAL is the latest addition in LIT (described in Chapter 3.3.2), therefore HEAL's architecture, as far as hardware is concerned, is almost the same as LIT's. Figure 4-8 is

an overview of HEAL's hardware architecture. To start with, a video wall and two projectors show the game interface in both the side and the floor of the interactive space. Two computers are also used, one for each side of the game interface. In our case, «Computer 1» is used for the video wall or else «Wall» side, while «Computer 2» is used for the floor projection or else «Floor» side. Both of the computers are connected with a router, providing the interaction between the two sides of the game. One Kinect2 sensor, positioned on the top right corner of the structure, is used in order to have a clear view of the players and capture their body movements. The Kinect2 sensor is connected to «Computer 2» and the data captured are sent through the entire network using the router.

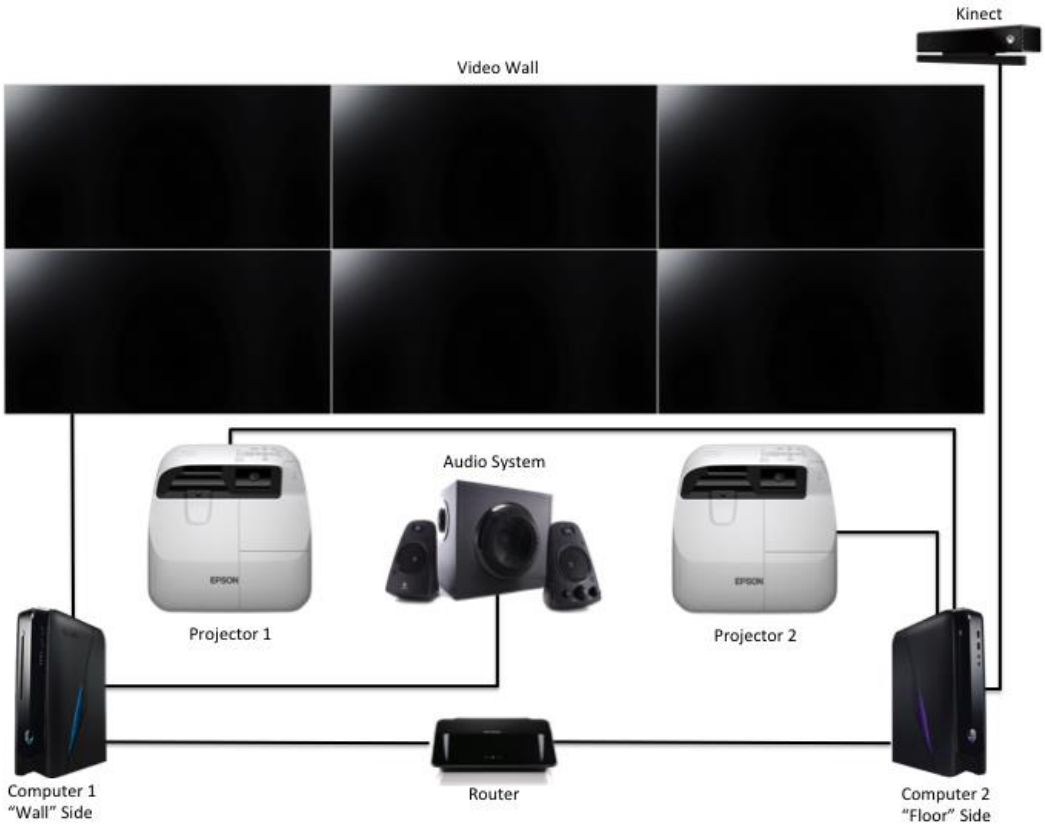


Figure 4-8. HEAL's Hardware Architecture.

The specifications of all the hardware equipment used can be viewed in the Table 4-2.

Table 4-2. Specifications of HEAL's hardware equipment.

Type of Equipment		Number of Elements	Equipment Information
Displays	Video Wall	One Video Wall Six Screens	55'' Direct-Lit LED Display Samsung (Model: UD55D)
	Projectors	Two	Epson EB-485W
Sensors		One	Kinect for Windows v.2
Computers		Two	Alienware X51-R2 Processor: Intel Core i3-4150 RAM: 6 GB Graphics Card: Nvidia GeForce GTX 745
Networking System	Router	One	DHP-1565 Wireless N PowerLine Gigabit Router
Audio System		One	Logitech Z623 2.1 Audio Surround System

4.2.6.2 Software Architecture

From the aspect of software, HEAL's class organisation can be seen in Figure 4-9. The software core consists of three main classes; The HEALStarter class which is the game initialization class, the GameplayManager which is responsible for the gameplay and the sequence of functions to be called, and the GUIManager which handles the GUI elements on each side (wall or floor) of the interface. The rest of the software hierarchy is straight forward, having the GUI classes initialized from the GUIManager, the classes related to the player and the body data managed by the GameplayManager and the network and setting classes handled by the HEALStarter.

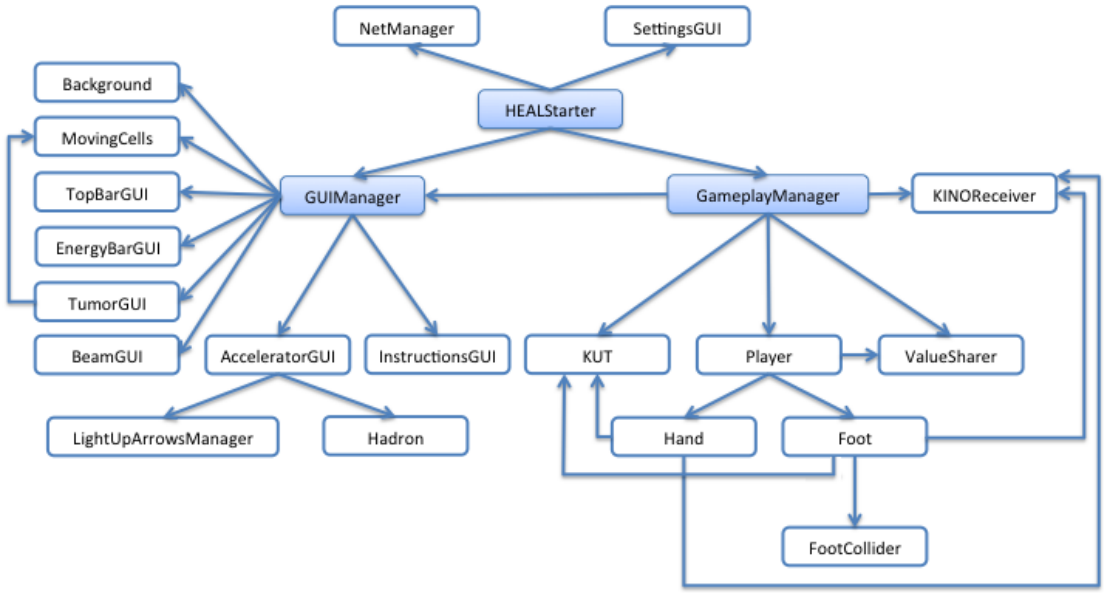


Figure 4-9. HEAL's software architecture. Rectangles represent classes while arrows represent object initialisations (not sub-classes).

4.2.6.3 Intercommunication Architecture

The communication architecture described above can also be seen in more detail in Figure 4-10. The Kinect2 sensor, connected to «Computer 2», captures the player body movements. The data deriving from these movements are being processed and transformed properly to match the interactive space coordinates. Then, they are transmitted through the network to «Computer 1», which is going to use them for updating the game controllers.

Figure 4-10. Communication process through hardware components.

4.2.7 Constraints

As mentioned before, Kinect is the sensor being used for capturing the users' movement. While the first generation of the Kinect sensors supported multiple sensors connected on one computer, the second generation came with limitations on that perspective allowing only one sensor per computer. Even though this change did not affect the current HEAL architecture, it should be mentioned in case of future versions of HEAL.

4.2.8 Overcoming Problems

The Kinect2 sensor uses two sensors, one depth and one colour camera sensor. To make sure that the sensor has no obstacles in its field of view, it was positioned two meters high and tilted in order to face the place where the user is supposed to stand. In this way, it was ensured that, in most of the cases, the user would be visible by the sensor.

However, the position as well as the rotation and tilting of the Kinect2 sensor urged the need of transforming the coordination system of the Kinect SDK as the coordinates returned did not reflect reality. To overcome this issue, transformation calculations needed to be applied in the received data in order to transform them relatively to the LIT space. The transformation was first implemented on the X and then on the Z axis, in order to take into consideration both the tilting and the rotation angle.

4.2.9 Implementation

In order to develop HEAL, several programming tools and libraries were used. The following subsections describe the main platform used as well as the tools and libraries used in order to implement HEAL.

4.2.9.1 Platform

For the development of the HEAL game, Unity3D [112] was chosen. Unity3D is a game engine platform, developed by Unity Technologies, aiming to help its users with the development of 3D games and applications. The platform provides a user-friendly environment and a variety of tools, thus, reducing the time and effort of making interactive content. Unity3D also offers the ability to target games to multiple platforms, including mobiles, desktops, the web, and consoles.

Unity3D users can choose either C# or JavaScript for developing their software. In the case of HEAL, we went with C# as the integration with the Kinect SDK would be faster and easier. Moreover, several libraries needed for this project were written in C#. These two reasons were important enough to exclude JavaScript as the development language scenario.

For HEAL, version 5.3.4f1 was used.

4.2.9.2 Tools and Libraries

The Kinect for Windows SDK is a software development kit that can be used to expand the possibilities of a Kinect sensor. The kit provides the tools and APIs, native and managed, needed in order to develop Kinect-enabled applications for Microsoft Windows. In the case of HEAL, the Kinect SDK was used to capture the joints positions of the players in order to recognize body movements such as pointing to a specific direction, raising hands or moving feet. For HEAL, version Kinect for Windows SDK 2.0 was used.

KINO (**KI**nect **NO**de) [113] is a library developed by the CERN MediaLab, serving as an interface between the Kinect SDK and the application. KINO captures and processes the data received from a Kinect sensor and then transmits them through the entire network,

allowing for multiple Kinect sensors to be connected to one application. The necessity of KINO was raised after the release of the version 2 Kinect sensor, as using more than one Kinect2 sensors in a computer was not supported anymore. KINO was used in HEAL as it provides an easier and more user-friendly API in developing a Kinect-enabled application. For HEAL, version 1.0 was used.

KUT (**K**INO **U**niversal **T**ransformer) [113] is another library developed by the CERN MediaLab, offering space-calibration functions for Kinect2 sensors. In HEAL, the Kinect2 sensor was positioned two meters high from the ground and was both rotated and tilted to face the player. This placing was decided for the sensors' unhindered functioning, in order to avoid people from walking in front of them. This positioning caused errors in calculating the coordinates of the players' joints. In order to overcome this problem, KUT was used for the calibration of the Kinect2 relatively to the interactive space. For HEAL, version 1.0 was used.

iTween [114] is a simple, powerful and easy to use animation system for Unity3D. This tool was primarily used to move specific user interface items as it made the development process faster and easier. For HEAL, version 2.0.5 was used.

4.3 Functionalities

In order to describe better the functionalities of HEAL, we are going to go through a usual usage case scenario.

4.3.1 Introduction information and Game Instructions

To start with, before a user enters the interactive space of LIT, HEAL encourages people to enter its space. Figure 4-11 and Figure 4-12 show HEAL's user interface before a user enters its interactive space.

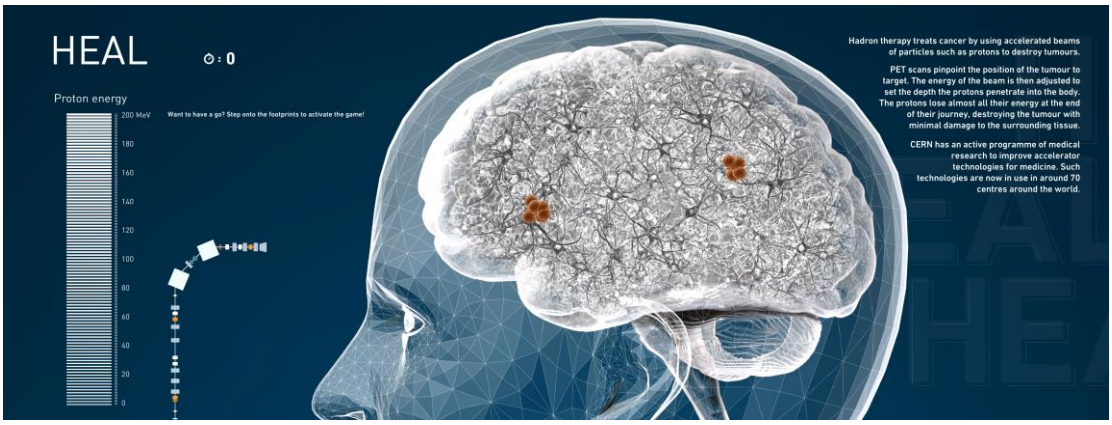


Figure 4-11. The "Wall" interface before someone stepped on the footprints on the "Floor" side. On the right side, general information on Hadron Therapy is displayed.

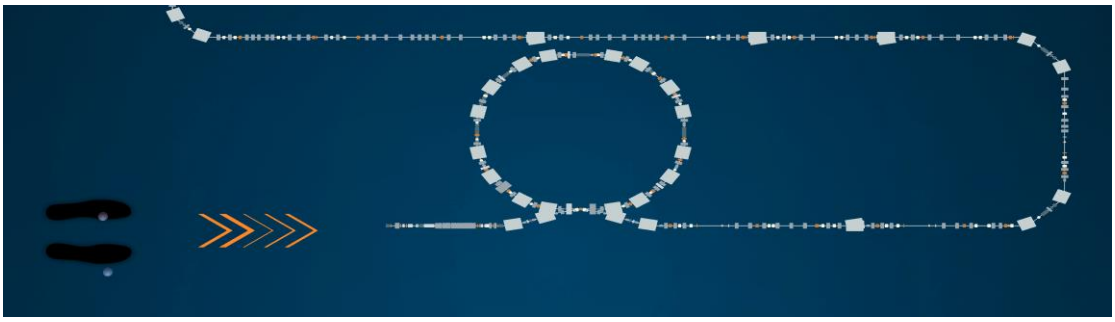


Figure 4-12. The "Floor" interface before someone stepped on the footprints shown on the left side.

Starting from the "Floor" side, players are provided with a Particle Accelerator. The background is kept simple in order for the different components of the accelerator to stand out. Two foot imprints indicate where users should stand in order to activate the game. Right in front of the imprints a set of flashing arrows, aiming to later motivate users to move one foot forward, is located. Finally, a pipe coming out from the

accelerator, passing to the “Wall” side and ending after being curved with the use of a magnet acts as the linkage between the two sides of the game.

On the “Wall” side, on the top the name “HEAL” as well as a timer, used to count the seconds taken by one player to destroy the cancer cells, are shown. The central and biggest part of the screen displays a humanoid head along with masses of moving cancer cells. A short description on what Hadron Therapy is and how is related to CERN is visible on the right side of the screen during the entire gameplay. On the left part of the screen a vertical bar with the caption “Proton Energy” is positioned. This bar, called the *Energy Bar*, will be the indicator of the selected amount of energy to be used for the protons to be emitted. Information text right next to the Energy bar is inviting visitors to stand onto the two-foot imprints shown on the “Floor” side. As soon as the presence of a person in the vicinity of the imprints area is detected, a sequence of instructions is set.

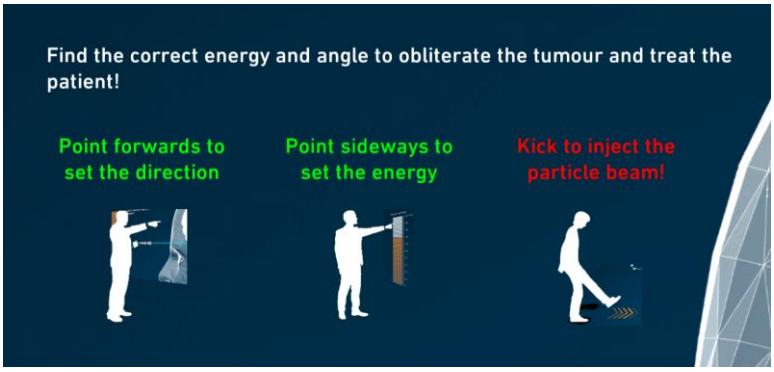


Figure 4-13. Set of instructions as shown on the "Wall" side of the HEAL interface.

The set of instructions describing how to use the game controllers are displayed on the «Wall» side using descriptive text and images (Figure 4-13). The instructions show how to control the energy and direction of the hadron beam, as well as the way to trigger it Displaying of the instructions happens only when a player is within the *activation area*, as defined by the foot imprints.

4.3.2 Setting Values

As soon as users enter the *activation area*, they can start playing the game. In order to interact with the game, they are invited to make gestures using their hands and feet. The gestures used by HEAL are: (a) the raising and (b) fixation of a hand for adjusting and setting the energy or direction of the hadron beam and (c) the kick of a foot for boosting it.

While the logical order of actions would be to first set the energy and direction of the hadron beam and then boost it, for simple and easy-to-use purposes the order of actions is not limited. However, the instructions' text is color-coded in order to indicate whether a parameter was set (green colour) or not (red colour). Colour-coding also exists in the visual representation of controls; while values are being modified by users both the energy bar and the direction preview have vibrant colours, while when "locked" they change to grey.

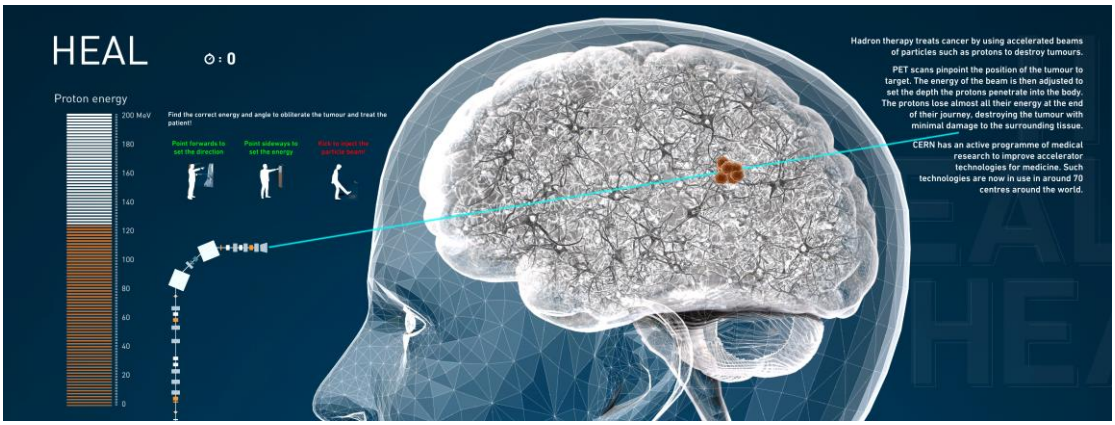


Figure 4-14. The HEAL interface when a player has selected both the energy and the direction of the hadron beam. The description text of both settings is green coloured, while the not completed action is red coloured.

4.3.2.1 Setting the Hadron Beam Energy

To set the amount of energy that will be given to the hadron beam users have to use their hand and point at the energy bar. To recognize this gesture, we measure the angle between the user's hand and the Kinect2 sensor. Since the Kinect2 sensor is positioned on the top right corner of the LIT structure and facing the interactive area, the angle we are looking for in order for a user to point at the energy bar is either close to 0° or 180°. To simulate the energy value input, we calculate how high or low the hand is by measuring the angle between the player's body and hand. The highest the user's hand is, the bigger the angle and thus the higher the energy. The lower the hand is, the smaller the angle and therefore the lower the energy.

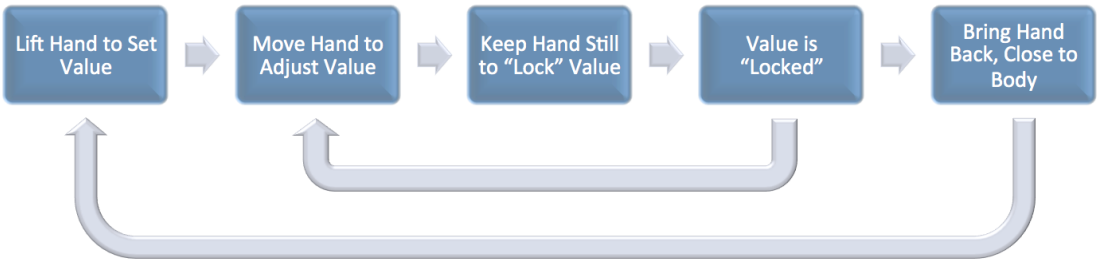


Figure 4-15. Sequence of actions a user has to perform to set a value on the HEAL interface.

As soon as players lift up their hand pointing at the energy bar, its colour changes to orange, indicating that this specific control is enabled.

To set or else "lock" the energy value, users need to hold their hand as still as possible to the desired angle for 1 second. As soon as the value is "locked", the information text related to the energy setting changes its colour from red to green. Also, the energy bar colour greys out and freezes at the "locked" value. In case players need to re-adjust the energy, they can either continue moving their hand, having the controller unlocked after 2 seconds, or just put their hand down and then lift it up again. Figure 4-15 is a diagram

of the sequence of moves a user needs to follow in order to complete the action of setting the attributed energy of the hadron beam.

When a user re-adjusts the energy, a greyed out indicator is shown on the background of the energy bar to indicate the last set energy value. In this way it is easier for users to know how much higher or lower they should go in order to set a better estimated energy value than their last selection or try.

4.3.2.2 Setting the Hadron Beam Direction

Setting the direction is relatively similar as setting the hadron beam energy. Users have to use their hands as before but point forwards, to the other side of the video wall. Calculation of the angles is the same, but the recognition of the pointing forward gesture is now detected by a 90° degree between the user's hand and the Kinect2 sensor. Once again, the higher the hand is, the higher the hadron beam will go, while the lower the hand is, the lower the hadron beam will go. The sequence of actions the user has to follow is similar to the one followed on setting the hadron beam energy, as previously shown in Figure 4-15.

To setup the hadron beam direction, players are asked to lift their hand up pointing forwards. As soon as they do, the colour of the direction preview changes to light blue, indicating that this specific control is enabled. The direction preview line, showing the path the hadron beam will have, follows the player's movements as she moves her hand. Having this direction preview available makes it easier for users to target the cancer cells. As soon as the value is "locked", the information text related to the direction setting changes its colour from red to green. Also, the direction preview freezes in the "locked" position and greys out. Keeping the direction preview visible at all times is useful for users to make a better estimation on the direction to set in their next try, in case they fail to target the cancel cells in their previous one.

In order to limit the number of errors in small angles, we needed to put some thresholds. In more detail, when a user's hand was not lifted enough, the detection of gestures could be problematic as the distinction was not possible due to close measurements of the angles. To overcome this issue, we have set as a lower threshold an angle of 30°.

4.3.2.3 Putting Hadron Therapy in Action

After setting both the energy and direction of the hadron beam to be injected, users can boost the hadron beam by using the controllers positioned on the «Floor» side of the user interface. To boost a hadron users should virtually kick on top of the flashing arrows area positioned on the "Floor" side. As soon as they kick, the relevant instructions text colour on the "Wall" side changes from red to green. To capture the boosting gesture we are transforming the user's feet coordinates captured from the Kinect2 sensor to coordinates relative to the interactive space and checking whether they are in between the bounds of the flashing arrows.

After its boosting, the hadron beam gets accelerated in the accelerator available on the «Floor» side (Figure 4-16) and then travels to the «Wall» side (Figure 4-17) by using a connecting pipe. The hadron beam then gets injected to the tumour cells on the «Wall» side in an effort to destroy them. In order for this to happen, both the energy and the direction should be set precisely to reach a tumour cell.

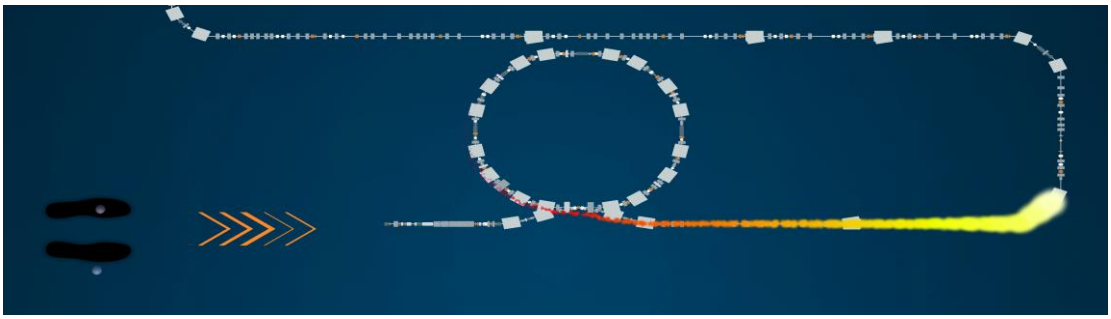


Figure 4-16. The "Floor" interface as soon as the user had kicked. The hadron beam gets accelerated.

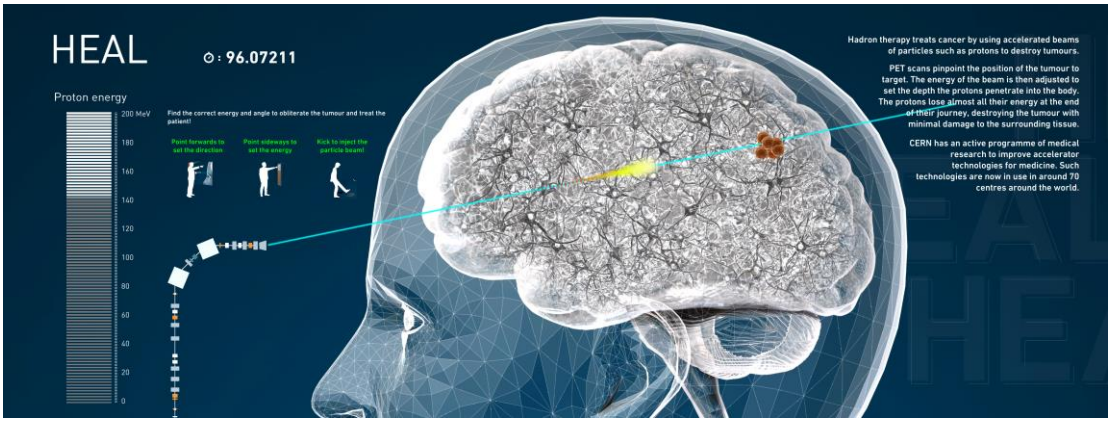


Figure 4-17. The "Wall" interface after the kick has happened. The hadron beam is directed to the direction the player has selected before.

There are three scenarios after a hadron beam is injected; (a) the hadron beam finds its target, (b) the hadron beam has the correct amount of energy but not the correct direction and (c) the hadron beam has the correct direction but not the proper energy. In the latter case there are two cases; (a) the energy was not enough to reach the tumour cell or (b) the energy was set too high and overpassed the tumour cell. In the case where the beam finds its target, the tumour cell gets destroyed while in the rest it stays intact.

As soon as the beam vanishes, and regardless of the outcome, all the instruction text colours turn back to red and the user has the opportunity to continue playing, following again the same instructions as before.

4.3.2.4 Beating cancer

To make the game more appealing and challenging [50] to its potential users, in HEAL's preliminary version cancer cells were spreading over time. However, taking into consideration preliminary evaluation's feedback, we later decided to discontinue this functionality and replace it with a timer counting the seconds it took a player to destroy the tumour cells. This was also a trigger for new users to beat not only cancer, but also their friends' best time.

5 Evaluation

CERN estimates that more than 110,000 people visit the organisation every year [87]. With all the more museums transforming from plain object-centred exhibitions into interactive, educational person-centred places engaging visitors and triggering them to get more interested in various subjects, CERN has made a major revamp of Microcosm with new exhibition items and content inaugurated.

The HEAL game was one of the new interactive media inaugurated into the new Microcosm exhibition, having a remarkable number of users every day. As mentioned before, HEAL intends to (a) inform visitors about Hadron Therapy and how it works, as well as (b) highlight CERN's involvement in other research fields, apart from physics and computer science, as well as its impact on our everyday lives through technological achievements. However, since HEAL deals with such a sensitive life-threatening health issue, cancer, the approach of the subject should be implemented really carefully. As many people have negative feelings on topics related to cancer, HEAL tries to also make its users feel more at ease with this issue, minimizing the negative mental and emotional impact that games on sensitive health-issues can have.

In addition to the above, HEAL also adopts a gesture-based method of inputting information to the system. Adjusting parameters and triggering events are implemented by the physical movement of hands and feet of the users. Increasing and decreasing values is achieved by moving up and down one's hands, while triggering is done by a

kick movement of one foot. Since this is not a widely used method of input, yet, and users are quite new to this kind of interaction, it should be studied whether such interaction methods are intuitive and easy-to-use to the users.

In order to be able to find out whether HEAL meets its purposes without having an unpleasant impact on visitors' psychology, a controlled experiment needs to be carried out. Thus, this study is designed to investigate and analyse the learnability and the psychological impact such interactive games dedicated on serious life-threatening health issues may have.

5.1 Experiment Design

Before proceeding to having an experiment, it is necessary to design it first. When designing an experiment, it is quite helpful to evaluate the factors that control our experiment. Moreover, it is also essential for better controlling the experiment and the sources of variation, as well as preventing unforeseen factors that might counterfeit our experiment or results.

5.1.1 Defining the research question

As mentioned before, HEAL was designed and developed around the following main objectives:

- Understanding what Hadron Therapy is and how it works.
- Understanding that serious health-diseases can be treatable.
- Highlighting CERN's involvement in other research fields, apart from physics and computer science.

- Highlighting CERN's impact on our everyday lives through technological achievements.
- Reviewing the learning outcome of experience enhancer games.
- Reviewing the mental and emotional impact that games on sensitive health-issues have on their users.

With most of CERN's visitors having (a) no or almost no knowledge or understanding in particle physics and (b) a wide age range, the provided material should be easy to understand as well as interesting enough to trigger visitors' interest in finding out more information about science after their visit at CERN. Time consumption should also be considered as visitors spend a limited amount of time on exhibitions. Durability of the information is also important as we need visitors to actually learn something and not lose the point of their visit due to excessive gamification. Consequently, information provision should be easy, interesting, durable and fast.

In order to achieve that, we therefore need to concentrate on game tasks that highlight the principals of Hadron Therapy and its connection to CERN. As described in Chapter 3.2 HEAL focuses on two factors, energy and direction, as those two parameters are the most important for Hadron Therapy treatment. Both of these factors are set on the "Wall" side of HEAL's interface. The accelerator on the "Floor" side is the connecting element between how Hadron Therapy works and CERN, serving both as a Hadron Therapy pillar and a technology deriving from CERN. Hence, in order to assure that the game metaphor is understood by the HEAL users, the parent task should be destroying, if not the entire, just a part of the tumour shown on the "Wall" side.

To determine whether HEAL's purpose was fulfilled, we need to research whether it served its purpose in the contexts of learnability, usability and engagingness. Metrics such as the completion of the task given and the time taken to achieve it, the ease in which visitors were able to handle the game controls, the willingness to continue

playing or even come back, are really important in defining whether HEAL was successful or not.

However, throughout the entire process we should also take into consideration important factors of variation of results. Infrared lighting, clothing, reduced mobility, previous experience with similar interactive environments, nationality, education level, age and gender are some of the factors that could cause faulty variations in our experiment results. In order to prevent this unpleasant possibility, we need to extensively record all factors that have an influence in our experiment.

5.1.2 Variable Enumeration

5.1.2.1 Independent Variables

Technique: To evaluate whether HEAL serves its purpose and is informative enough, we need to compare it with other learning tools. MIOs usually present their information in the means of text, pictures and videos. These broadly used tools of learning provide MIOs control of the information they wish to focus on and of the speed at which information is presented. However, most used presentation tools do not cover entirely the needs of interactivity we need for this experiment. Common presentation applications provide either linear presentations without giving its users the opportunity to choose the order in which they want to review information, or limit their interactivity with common media such as images, videos, links, etc.

5.1.2.2 Dependent Variables

Speed: The speed at which a user is completing the game goal, which is destroying the entire tumour, is a way to measure both the usability and the clarity of the game. In the unpleasant case of a user having problems with following the instructions or the gameplay scenario, the amount of completion time will be either high or indefinable, in

case the user gives up before completing the goal of the game. In each case, time is a simple and quite representative measure for deciding whether the gameplay scenario is clear and the game controls usable.

Engagement: The engagement of users is an important variable as it shows how interesting and fun users find the game and whether they are willing to play it again or even suggest it to their friends [115].

Learning: When the users are able to respond correctly to questions related with the educational target of the game, then we can assume that the learning purpose of the game was fulfilled. In HEAL, in order to be able to use effectively the Hadron Therapy, the user has to understand that both energy and direction need to be precisely adjusted to the cancer cells and a particle accelerator needs to be operated for the injection of the hadrons. If after playing the game users can confidently answer that the important factors in Hadron Therapy are energy and direction, then HEAL has successfully delivered its message.

5.1.2.3 Control Variables

Location: In order to eliminate the effects of cofounds on the outcomes of our experiment, we need to make sure that the experiment takes place in the same conditions. First of all, the location in which the experiment takes place needs to be the same throughout the process. Location variation can cause problems, especially in our case where we use Kinect2 sensors as they are quite sensitive to infrared lighting. In our case the experiment took place in the CERN Microcosm museum, located at CERN, in Meyrin, Switzerland. Chapter 3.4 describes the reasons of selecting Microcosm. For our experiment the as called «Discovery Area», a corner inside the Microcosm museum, where lighting conditions are ideal for the proper functioning of Kinect2 sensors, was chosen.

System Software and Architecture: Another important factor is the system in which the experiment takes place and its configuration. System variations can have an effect on the software performance, resulting into cofounding of the experiment results. To avoid this problem, the architecture, machines, software and software versions were not changed during the experiment process.

Instructions: Instructions on how to use the game were also provided in a text form while a user was interacting with HEAL. The instructions were specific and same to everyone using the game.

Experiment time: Finally, every user was given as much time as she wanted to play the game. In that way, we could observe whether the user wanted to play more or just give up before even completing the goal of the game.

5.1.2.4 Random Variables

Age, gender, nationality and educational background of the visitors are variables that are clearly not possible to be controlled in the experiment. To prevent distortion of results, we avoided putting people having the same characteristic in one group, as for example all women in one group and all men in another.

Clothing is also important as Kinect2 sensors might have problems identifying the skeleton of a person when wearing specific fabrics or shoes. In a case when a visitor was wearing problematic clothing, we would either ask her to remove it if possible, or we excluded the visitor from the experiment procedure.

5.1.3 Arrange Conditions

To be able to participant in the experiment, a visitor should: (a) have never used HEAL before, and (b) wear clothing and shoes that do not cause malfunctioning of the Kinect2 sensors.

To conduct the experiment, participants will have to use the HEAL application and answer questionnaires right after their HEAL experience. In order to ensure that the results are intact, the involvement of a lot of participants coming from different backgrounds to the experiment is essential.

5.1.4 Setting Instructions

While playing HEAL, participants were provided with a set of instructions, guiding them through the basic steps of using either software. The instructions were in the form of text, followed by descriptive images.

5.1.5 Setting Procedures

Setting a procedure which participants are asked to follow was also crucial in order to ensure that every participant has the same experience and for our experiment to be reproducible if needed be someone else. Below are described all steps followed during our experiments:

Step 1: Recruiting Participants. Participants would have to visit MIOs exhibition, in this case Microcosm.

Step 2: Consent Form. Visitors were given a consent form to read before participating in the experiment (Appendix includes the handed Cover Letter). The consent form had information on the experiment procedure as well as information about the privacy of their data. The goal of the

experiment was also explained. In case they gave consent, then they could move to Step 3, otherwise they were eliminated from the procedure.

Step 3: Main experiment. Participants used the corresponding software as long as they wished, following the instructions provided during their play.

Step 4: Questionnaire. Participants were asked to fill in a questionnaire after their experience with the software.

Step 5: Debriefing.

5.2 Preliminary Evaluation

An evaluation of the initial prototype was conducted to provide us with a preliminary assessment of the quality of the user experience. This was necessary to not only evaluate the usability of the game in terms of its user interface and stability, but also to gather data and experience for designing and running the formal study.

In order to achieve that, we created a set of questions, covering as many factors affecting the quality of the visitor experience as possible. Questionnaires were developed from findings of previous studies [116-120]. These factors included: (a) satisfaction, (b) engagement, (c) learnability, (d) qualia, (e) motivation/triggering, (f) ease of use, (g) ease of learning, (h) gameplay clarity and (i) the psychological impact. Covering all these factors resulted in 129 statements, a large enough number to discourage a visitor from participating to the evaluation. To alleviate this potential problem, we created three separate questionnaires, each of which covering different factors.

Statements were worded carefully and long, ambiguous, leading and biased questions were avoided. For all three questionnaires, three types of questions were used.

Most of the statements were presented in scales as Likert items from 1 meaning "strongly disagree" to 5 meaning "strongly agree". All of the questionnaires included demographics questions, most of which were of type multiple choice. In these questions, participants would need to choose just one response from a list of alternatives. Finally, questions that promoted participants to express their opinions on the game were open, allowing respondents to formulate their own statements. Since open questions are more difficult to analyse, only two questions of this type were included.

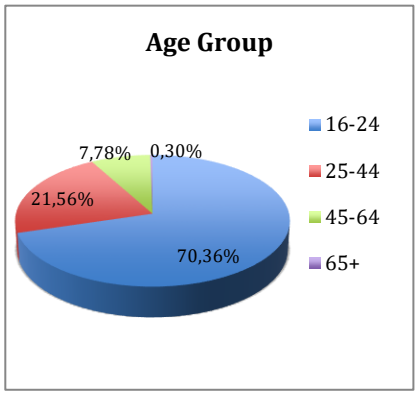
Questionnaires were available in five different languages: English, French, German, Italian and Greek. The latest evaluation [121] of the museum showed that most of its visitors were speaking one of these languages, apart from Greek. By providing questionnaires in the visitors' mother language, misinterpretations would be minimized and visitors would feel more comfortable responding.

In every evaluation there will be missing data occurring for different reasons. In this study, the following types of non-responses were identified and questionnaires were excluded from the evaluation:

1. The respondent has not responded to one or more questions. The reason might have been by choice or simple overlooking of the question(s).
2. Response was invalid, e.g. where only one answer was required but the respondent selected several responses.

The preliminary evaluation was conducted at Microcosm, CERN's most popular and visited permanent exhibition. HEAL was available in the "Discoveries" area of Microcosm for approximately a month (from March 15th to April 20th 2016) from 8:30 to 17:30. During this period, three hundred thirty four random visitors agreed on participating in the preliminary evaluation, two hundred eleven of who were men (63.17%). Most of the participants were from 16 to 24 years old (70.36%) and were part

of an organised visit (66.46%). All participants were random visitors of Microcosm who could speak fluently and understand the English language.



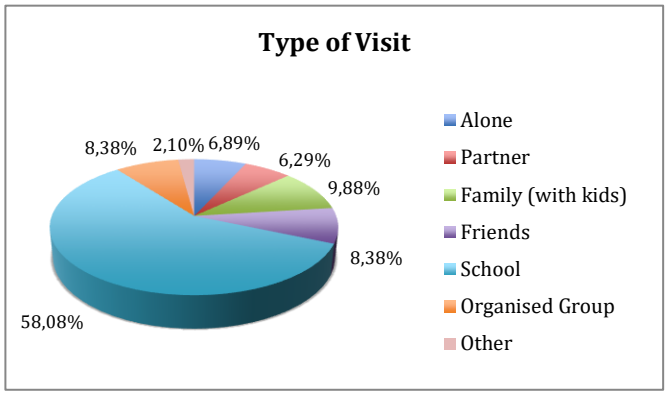


Chart 5-1. Participants' Age Group

Chart 5-2. Participants' Type of Visit

Table 5-1. Distribution of participants by age and sex

	16-24 (total %)	25-44 (total %)	45-64 (total %)	65+ (total %)	Total	Percentage
Male (total %)	153 (45.81%)	45 (13.47%)	12 (3.59%)	1 (0.30%)	211	63.17%
Female (total %)	82 (24.55%)	27 (8.08%)	14 (4.19%)	0 (0.00%)	123	36.83%
Total	235	72	26	1	334	100,00%

5.2.1 Results

The results of the preliminary evaluation were encouraging as HEAL seemed to be very appealing to everyone, especially teenagers. The prototype provided a fun game environment while providing enough information for users to understand (a) the purpose of the game and (b) how it is connected to CERN, and discern (c) the problem

presented and (d) the solution offered, thus leaving CERN (e) having an overview of the entire method of treatment.

Our observations identified the interactivity provided as a particularly attractive design feature. Visitors often became more excited as they realized they could interact with the game controls just by using body movements. This seemed to make to game more fun and interesting, while being educational by introducing some concepts about the angle and the amount of energy needed to succeed in the game. Table 5-2 shows the comments provided by the users.

Table 5-2. Participants input on the elements of the game that they liked.

What visitors liked	#	What visitors liked	#
Interactivity	55	Simplicity	7
Fun / Enjoyable	24	Clarity	6
Graphics	15	Ease of Learning	6
Educational / Informative	11	Easy to play	5
Understandable	10	Usability	5
Gameplay	10	Connection with medicine	4
Interesting	9	Fun to learn	3

The preliminary evaluation also revealed some minor bugs in the game prototype that were later eliminated and tested before the formal evaluation of HEAL. The bugs were mainly related to the way the game was recognizing players and their movements, especially when another visitor was entering the interactive space. Table 5-3 shows the most occurred suggestions for improvement by users. On the top of the list, users expressed the need of further explanation of what HEAL is about and better instructions on how to play the game. To achieve that, a more detailed description of Hadron Therapy, as well as images accompanying the existing text instructions were added to

the game interface. Problems related to the Kinect2 sensor were identified and eliminated. Minor changes have also been applied to the gameplay since some participants seemed to have no positive feelings with some gameplay actions as for example the spreading of the cancer cells over time. Finally, suggestions such as climaxing difficulty were not adopted as we believe that a game such as HEAL should be fast to play and simple enough to not keep the users more than 5 minutes as explained in previous chapters.

Table 5-3. Participants' suggestions for improvement.

Suggestion for Improvement	#	Suggestion for Improvement	#
More instructions / explanation	28	Multiplayer	6
Improve sensor accuracy / sensibility	22	Difficulty (Harder to win)	6
Improve Kinect reception	13	Improve aiming precision	6
Better input feedback	6	Climax difficulty (More levels)	3

Results of each questionnaire are described below in more detail.

5.2.1.2 Questionnaire 1

The first questionnaire included questions for five factors:

1. Satisfaction: whether the game is interesting to use and met the expectations of its users.
2. Engagement: whether the game was engaging enough to keep playing.
3. Learnability: whether the information is presented in meaningful ways.
4. Qualia: whether the game provided a conscious experience.
5. Motivation/Triggering: whether the game triggered its users to learn more about its topic after their visit.

Appendix includes Questionnaire 1 of Preliminary Evaluation

One hundred and ten participants completed the first questionnaire (41 women, 69 men) with most of them being between 16 and 24 years old (69.09%). Seventy-four participants (67.27%) were part of a group visit while a quite impressive number of participants (60.9%) travelled more than 100 kilometres to visit CERN. More than sixty-five participants (>59.09%) visited CERN for educational purposes as shown in Chart 5-6. Only two participants admitted having visited the organisation before, meaning that for the 98.18% of participants this was the first time visiting CERN.

Table 5-4. Questionnaire 1 - Distribution of participants by age and sex.

	16-24 (total %)	25-44 (total %)	45-64 (total %)	65+ (total %)	Total	Percentage
Male (total %)	43 (39.09%)	22 (20.00%)	4 (3.64%)	0 (0.00%)	69	62,73%
Female (total %)	33 (30.00%)	5 (4.55%)	3 (2.73%)	0 (0.00%)	41	37,27%
Total	76	27	7	0	110	
Percentage	69,09%	24,55%	6,36%	0%		100,00%

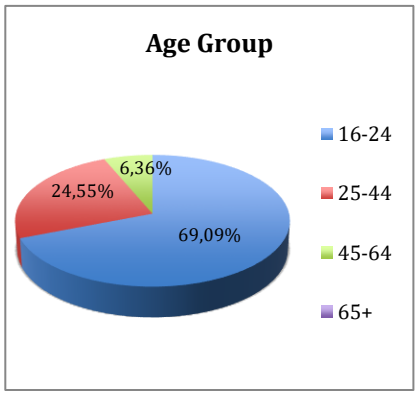


Chart 5-3. Questionnaire 1 - Participants' Age Group

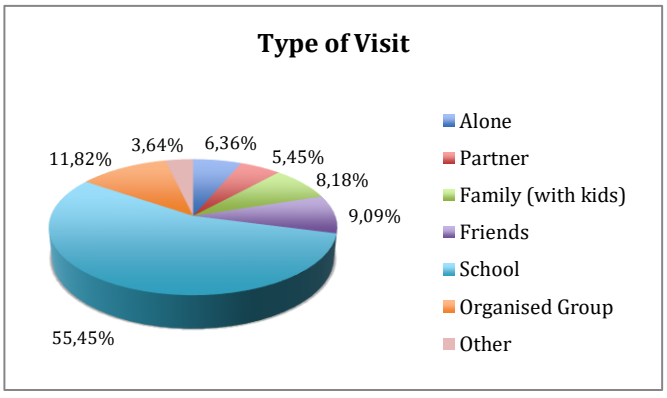


Chart 5-4. Questionnaire 1 - Participants' Type of Visit

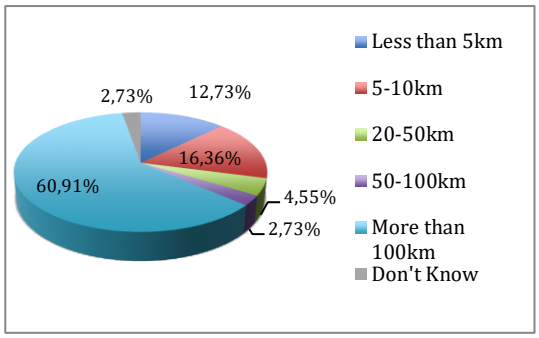


Chart 5-5. Questionnaire 1 - Participants' Travel Distance to visit CERN

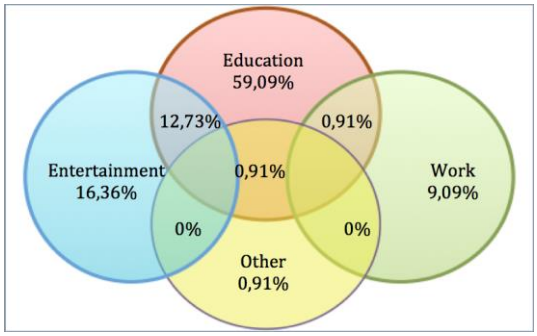


Chart 5-6. Questionnaire 1 - Participants' Visit Purpose

Almost all participants agreed that HEAL was fun to use (99.09%). A similar percentage (94.55%) admitted that HEAL kept their interest thought-out its use. In relation to the question of whether they would like to play again 89.09% stated that the game was still fun to play after one try and 82.73% that they would like to play again. Forty-eight participants (43.64%) thought the game was easy to win, but only four of them suggested making it more difficult. Only 4.55% admitted there were times when they wanted to give up playing while 60.91% would have loved to play longer. In general, participants were quite engaged to HEAL since 68.18% felt absorbed by the game; a fact both confirmed and reinforced by the 83.64% of the total evaluation participants who reported that they were interested in seeing how the games' events would progress. Almost half of the participants (43.64%) admitted having forgotten about everything else while playing. Finally, more than half of the participants (55.45%) were in suspense about whether they would win or lose the game.

Regarding the learning process, statistics were really encouraging. Most of the participants (91.82%) believed that the goal of the game was clear, similarly to the presentation of Hadron Therapy (82.73%). A similar percentage (90.91%) agreed that the scope of the game was clearly understood. Hence, it comes as no surprise that 72.73% of the participants said that by using the game they learnt what Hadron Therapy is and how it works. In addition to the above, the majority of participants stated that

HEAL enhanced their learning process (74.55%) or their exhibition visit (94.55%). The game technology used by the game (sensors, animation, graphics, sound) was referred to as a necessary factor for the visitor's learning process (89.09%). Same was the percentage of participants who stated that HEAL wouldn't be as fun if they were using an input device such as a mouse, keyboard, joystick (89.09%). Overall, 92.73% of participants enjoyed learning in such environment while 87.27% believes that they could learn more in such an environment. It was also recommended that such games should be used more frequently in learning (91.82%) and supplement traditional learning approaches (89.09%).

Seven out of ten (73.64%) participants stated that while playing they were supported positively from their peers. While most of the participants answered that they would recommend HEAL to a friend (82.27%), only some of them (21.82%) would like to share their score on Social Media.

As mentioned before, since HEAL deals with cancer, approaching of the subject should be implemented really carefully. The playful side should be kept in order to impart a pleasant approach, but in a reasonable manner to not make the game childish enough to trivialize such a sensitive life-threatening health issue or the image of a significant worldwide organisation. Luckily, only 10.91% of the participants thought that HEAL was childish.

After playing the game, more than half of the participants expressed that wanted to learn more about science (61.82%), or CERN technologies (79.09%), or specifically hadron therapy (76.36%). Out of fourteen people who have stated not being interested in CERN before their visit, after playing HEAL, ten (71.42%) claimed wanting to learn more about hadron therapy and eleven (78.57%) about science and CERN technologies.

In another question, while more than half of the participants (53.64%) agreed that a two-player competitive version of HEAL would be more entertaining, 82.81% of them admitted that the single player version is more suitable since it describes better how hadron therapy works. As shown in Chart 5-8, sixty-four participants (58.18%) voted in total the single player version as the best describing one.

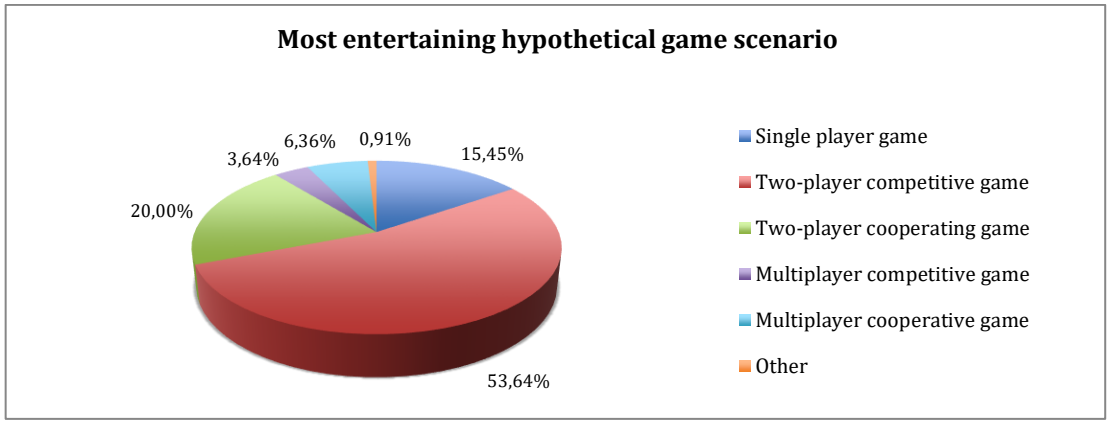


Chart 5-7. Questionnaire 1 - Participants' Answers of what they believe it would be the most entertaining game scenario.

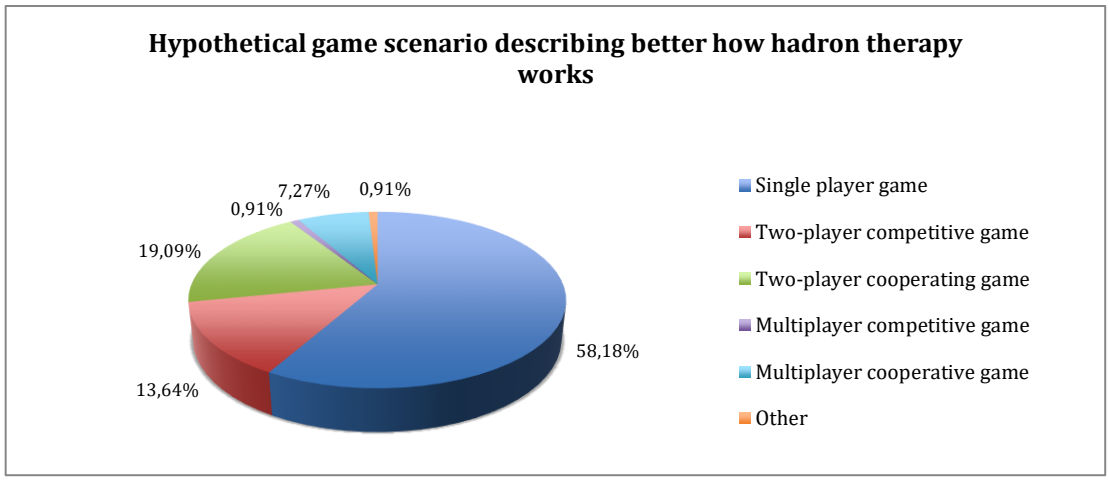


Chart 5-8. Questionnaire 1 - Participants' Answers of what they believe it would be the best describing game scenario on how hadron therapy works.

Overall, all responders of Questionnaire 1 stated having a good experience (Good – 43.64%, Excellent – 56.36%) of HEAL.

5.2.1.3 Questionnaire 2

The second questionnaire included questions for four factors:

1. Ease of use: how quickly expert users can accomplish tasks once they have learned to play the game
2. Ease of learning: how easy it is for first time novice and casual users to figure out how to play the game
3. Gameplay Clarity: whether the game contained all information necessary to evaluate a position and determine the correct play
4. Satisfaction: the user's overall satisfaction with the game experience.

Appendix includes Questionnaire 2 of Preliminary Evaluation.

Table 5-5. Questionnaire 2 - Distribution of participants by age and sex.

	16-24 (total %)	25-44 (total %)	45-64 (total %)	65+ (total %)	Total	Percentage
Male (total %)	53 (47.75%)	16 (14.41%)	4 (3.60%)	0 (0.00%)	73	65,77%
Female (total %)	21 (18.92%)	11 (9.91%)	6 (5.41%)	0 (0.00%)	38	34,23%
Total	74	27	10	0	111	
Percentage	66,67%	24,32%	9,01%	0%		100,00%

One hundred and eleven participants completed the second questionnaire (38 women, 73 men) with most of them being between 16 and 24 years old (66.67%). Sixty-two participants (55.85%) were part of a group visit while a quite impressive number of participants (62.16%) travelled more than 100 kilometres to visit CERN. More than sixty-three participants (>56.76%) visited CERN for educational purposes, as shown in

Chart 5-12. Only three participants admitted having visited CERN before, meaning that for the 97.3% of the participants this was the first time visiting CERN.

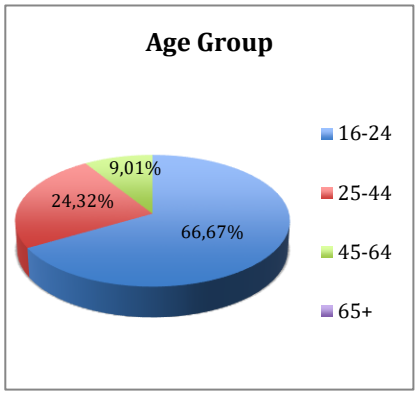


Chart 5-9. Questionnaire 2 - Participants' Age Group

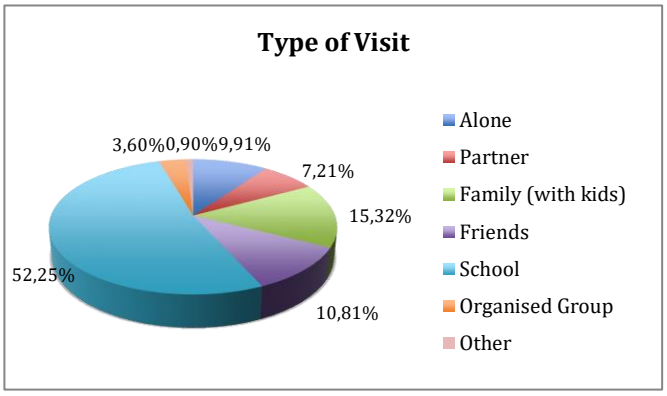


Chart 5-10. Questionnaire 2 - Participants' Type of Visit

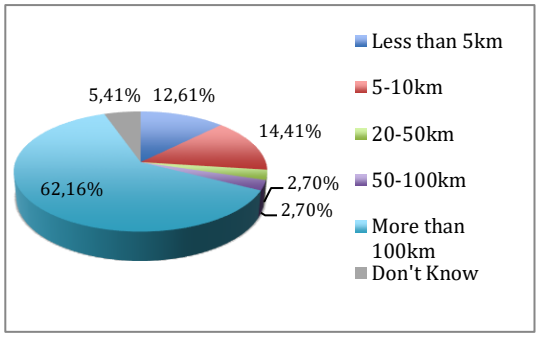


Chart 5-11. Questionnaire 2 - Participants' Travel Distance to visit CERN

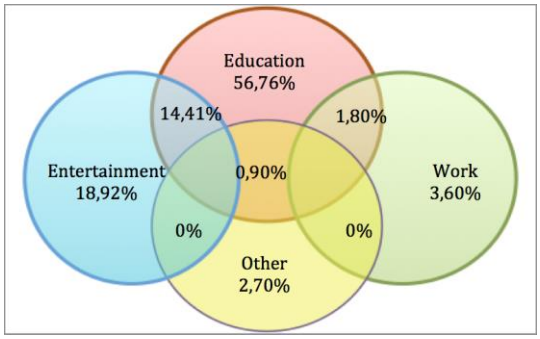


Chart 5-12. Questionnaire 2 - Participants' Visit Purpose

Almost all participants agreed that HEAL was easy and simple to use (92.79%). A similar percentage said that they didn't find the game difficult (87.39%) or tiring (79.28%) to operate. 84.68% of the participants felt confident operating the game. Participants also described the game as effortless (72.97%). Fifty-two participants (46.85%) claimed that they could not play the game without instructions, contrary to thirty-three participants (32.43%) believing otherwise. 90.99% mentioned that they could recover quickly and easily from mistakes (e.g. wrong amount of energy or direction), while 70.27% stated that they could play the game successfully, thus vanishing cancer cells, every time. In

relation to the question of whether any inconsistencies were noticed while using it, 72.07% responded negatively. Regarding the game complexity, participants (89.19%) didn't think that the game was unnecessary complex; while only 9.91% of the participants in total admitted that they wanted to give up while playing.

Regarding the ease of learning, statistics were really encouraging. Most of the participants (97,30%) stated that HEAL was easy to learn to play. Likewise, 89,49% of the participants didn't think that a lot of things were essential to learn before they could play the game. Hence, it comes as no surprise that (a) 97,30% of the participants learned to play the game quickly, (b) 99,10% easily memorised the game instructions, (c) 89,19% didn't believe that the game controls were difficult to understand, and (d) 87,39% claimed that they quickly became good at playing HEAL. It is important to mention that only 36,94% of the participants admitted having a strong experience with the X-Box Kinect or Wii sensors.

Since more than half of the participants (63,06%) had no strong experience with either the X-Box Kinect or Wii sensors, it is quite interesting to take a deeper look into their game experience regarding the ease of learning. 98,11% stated that HEAL was easy and fast to learn to play. In addition, 84,91% admitted becoming quickly good at it while 92,45% said the controls of the game were not difficult to understand. In other words, regardless of the users' previous experience with either the X-Box Kinect or any other similar sensors, the evaluation results show that HEAL fulfilled its purpose regarding the ease of learning.

In relation to the gameplay clarity, participants mentioned that information was presented in an understandable manner (77,48%). Not only that, they also agreed that there was a clear feedback provided for their actions (69,37%). Only a small portion of participants claimed having difficulties while playing HEAL. In more detail, 8,11% of the participants admitted not knowing what to do while playing the game, 2,70% got

confused about which of the two sides (floor or wall) they should look at while playing the game, and only one participant got distracted by elements on either side (floor or wall) of the game.

After playing the game, participants admitted enjoying playing the game (96,40%). Most of them mentioned that they would have loved to play longer (76,58%). 86,49% said that they would like to play HEAL again. Only eleven participants thought the game was not easy to win (9,91%). Two participants (1,80%) stated that the game goal was not clear.

Overall, all responders of Questionnaire 2 stated having a good experience (Good - 44,14%, Excellent – 51,35%) of HEAL.

5.2.1.4 Questionnaire 3

The third questionnaire was entirely referring to the psychological impact of HEAL to its users. Various studies have shown that games have an effect on the emotions of their users. HEAL is an effort to approach a quite serious and sensitive subject in a playful way, thus it is quite interesting to study the possible change of emotions while and after playing the game.

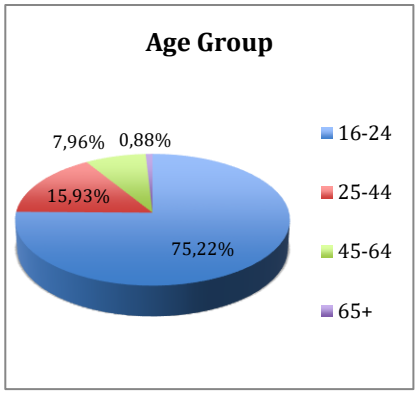
A set of questions followed by a Big Five questionnaire was handed to the evaluation participants. The reason of including Big Five questions to the evaluation question is to study further participants' responses in relation to their personalities.

Appendix includes Questionnaire 3 of Preliminary Evaluation.

One hundred and thirteen participants completed the second questionnaire (44 women, 69 men) with most of them being between 16 and 24 years old (75.22%). Eighty-six participants (76.10%) were part of a group visit (Chart 5-14).

Table 5-6. Questionnaire 3 - Distribution of participants by age and sex.

	16-24 (total %)	25-44 (total %)	45-64 (total %)	65+ (total %)	Total (total %)	Percentage
Male (total %)	57 (50.44%)	7 (6.19%)	4 (3.54%)	1 (0.88%)	69	61,06%
Female (total %)	28 (24.78%)	11 (9.73%)	5 (4.42%)	0 (0.00%)	44	38,94%
Total	85	18	9	1	113	
Percentage	75,22%	15,93%	7,96%	0,88%		100,00%



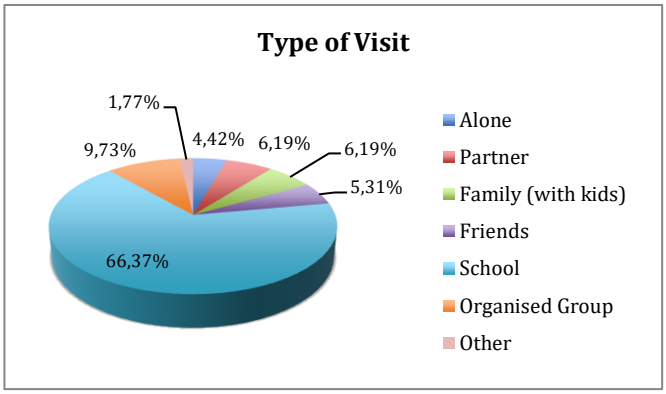


Chart 5-13. Questionnaire 3 - Participants' Age Group

Chart 5-14. Questionnaire 3 - Participants' Type of Visit

Eighteen participants (15.93%) mentioned feeling like they were harming the patient while playing. However, this percentage gets much higher when participants were asked whether they felt the same that by letting the cancer cells spread over time (37.17%), a functionality available only in the preliminary version of the game. Chart 5-15 shows an overview of the answers regarding this question. On the other side, 73.45% of the participants agreed that the game graphics helped to not feel emotionally attached to the patient they were treating. A possible reason could be the use of a humanoid head

instead of a more realistic one. In any case, since the number of participants annoyed by the cancer spreading was quite high, it was decided that the tumour growth gameplay feature would be removed from HEAL's formal evaluation.

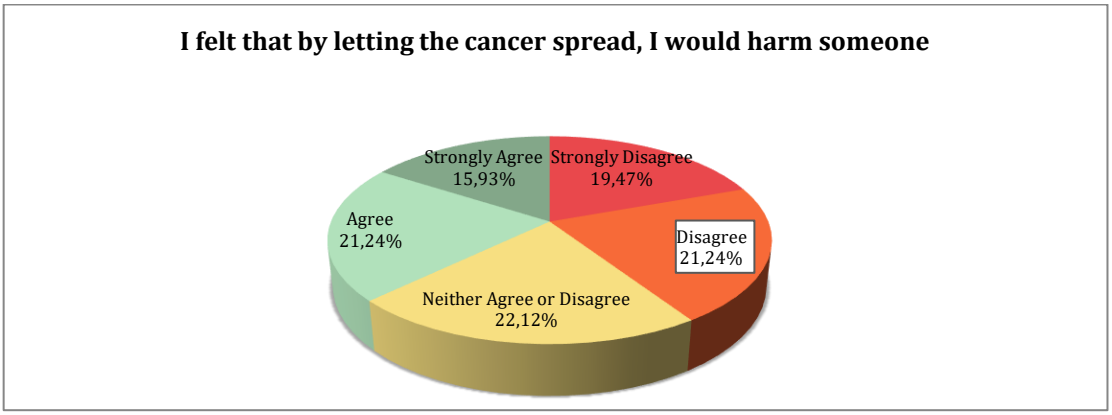
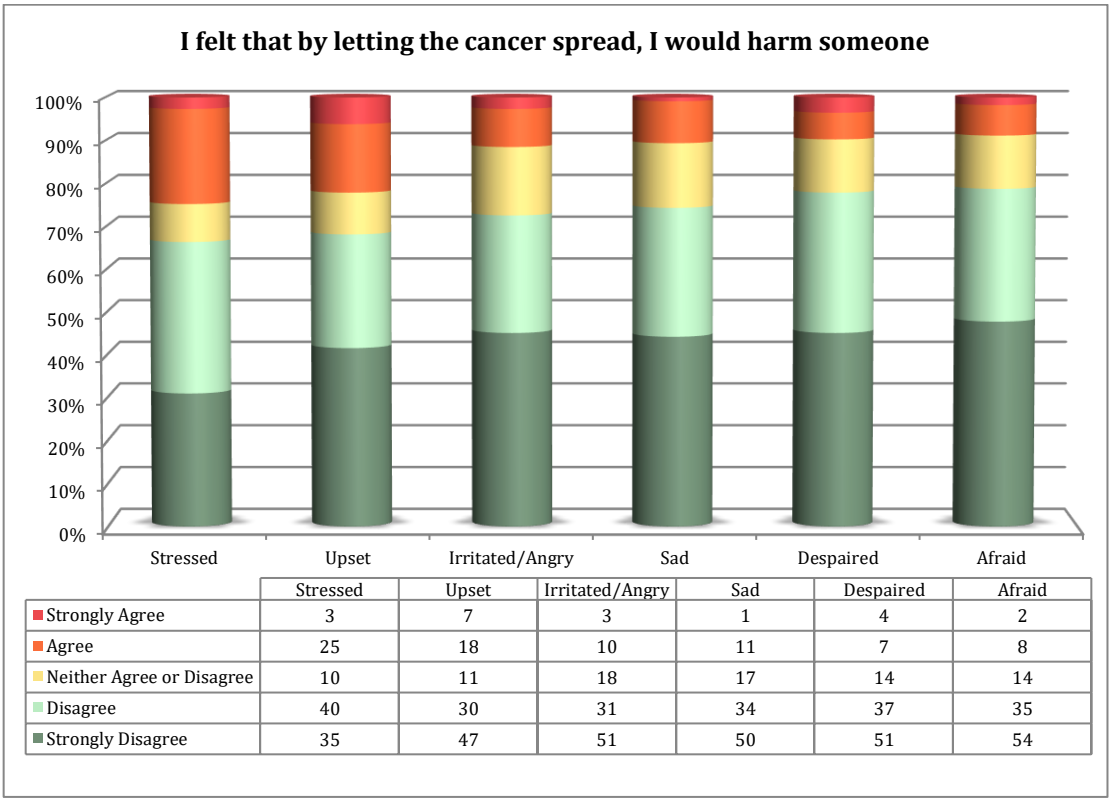


Chart 5-15. Questionnaire 3 - Participants' Answers on their sense of hurting someone regarding the "cancer cells spreading" game element.



	Stressed	Upset	Irritated/Angry	Sad	Despaired	Afraid
Strongly Agree	3	7	3	1	4	2
Agree	25	18	10	11	7	8
Neither Agree or Disagree	10	11	18	17	14	14
Disagree	40	30	31	34	37	35
Strongly Disagree	35	47	51	50	51	54

Chart 5-16. Questionnaire 3 - Participants' Answers on their feelings regarding the "cancer cells spreading" game element.

Despite this, participants had a good emotional experience while playing HEAL. 84,96% felt happy for healing cancer while 82,30% felt a sense of satisfaction and achievement while playing. More than half of the participants felt like they were helping the patient (63,72%). A similar percentage (68,14%) felt responsible for curing the patient.

In other questions related to the emotions the participants had while playing the game, 24.78% felt stressed, 22.12% upset, 11.50% angry or irritated, 10.62% sad, 9.73% despaired, and 8.85% afraid. Chart 5-16 shows participants' answers. In general participants felt confident about facing cancer (61.95%). More than half of them stated feeling powerful (60.18%) while playing HEAL. A similar percentage (60.18%) didn't think that dealing with cancer triggered negative emotions.

As mentioned above, participants were also asked to complete a Big Five questionnaire in order to further study whether their responses were closely associated to their personality profile. Chart 5-17 shows an overview of the participants' personalities as assessed by the Big Five questionnaire.

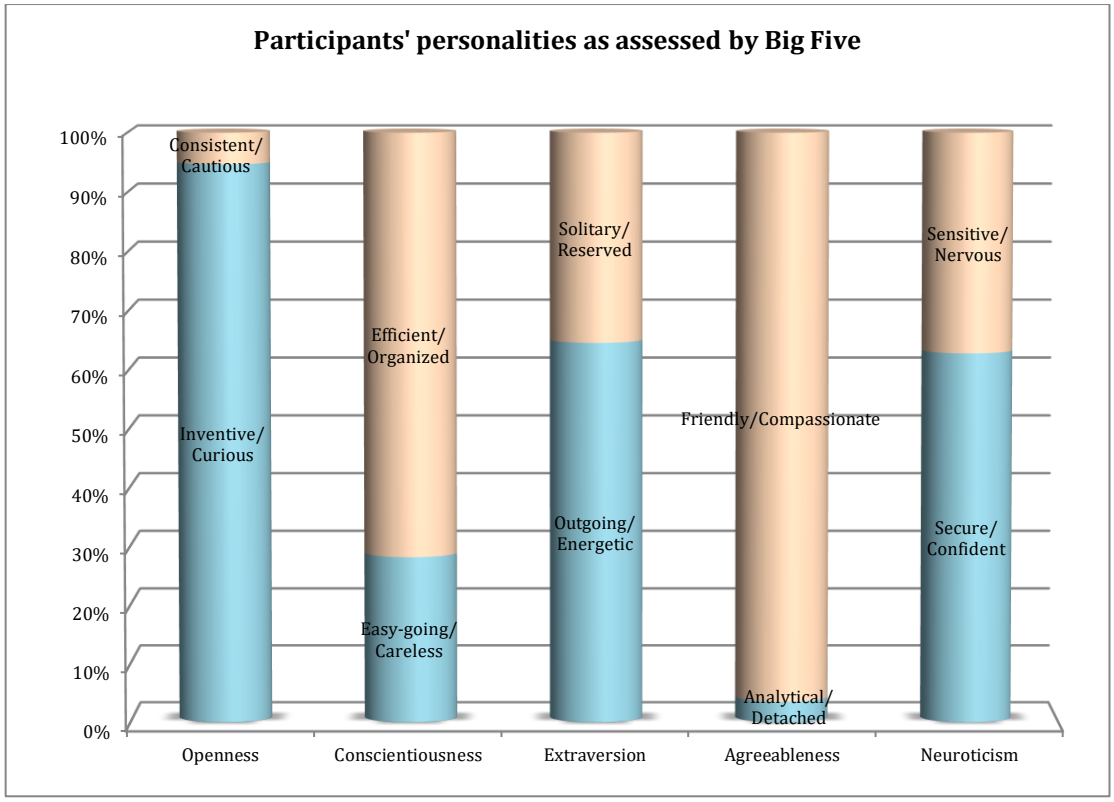


Chart 5-17. Questionnaire 3 - Distribution of participants' personalities as pairs of Big Five factors.

It is quite noteworthy to mention that 61,90% of the participants scoring high on Neuroticism stated that HEAL did not trigger any negative emotions. The same applied to a similar percentage of participants with high score on Agreeableness (59,63%). In more detail, 69,05% of the first category participants did not get sad while playing the game. Moreover, 64,29% of the same category said that they did not get upset while playing HEAL. Only 14,29% of the participants scoring high on Neuroticism claimed feeling angry while playing. Overall, only one fifth (20,34%) of participants scoring high on Neuroticism felt sad, upset or angry.

After playing the game, participants admitted feeling stronger against cancer (59,29%). A quite high percentage expressed feeling hopeful about the future (74,34%) while more than half of the total participants said that they feel stronger against cancer. Finally, 77,88% mentioned feeling optimistic after playing the game.

5.3 Formal Evaluation

The formal evaluation of HEAL took place one week after the preliminary evaluation. Using the latter one's data and experience, the formal study was designed to cover any missing spots or clarify uncertainties the preliminary evaluation showed.

The questionnaires handed out to the participants were much shorter and included more targeted and essential questions, focusing on evaluating the user experience and the learning processes used as well as on examining the impacts to the users' psychology. Appendix includes Formal Evaluation Questionnaire.

In total, 24 statements have been included in only one questionnaire. Statements were worded carefully and long, ambiguous, leading and biased questions were avoided. Three types of questions were used: likert, multiple choice and open questions. Most of the statements were presented in scales as Likert items from 1 meaning "strongly disagree" to 5 meaning "strongly agree". All of the questionnaires included demographics questions, most of which were of type multiple choice. In these questions, participants would need to choose just one response from a list of alternatives. Finally, one question that promoted participants to express their life experience was open, allowing respondents to formulate their own statements.

In this study, the following types of non-responses were identified and questionnaires were excluded from the evaluation:

1. The respondent has not responded to one or more questions. The reason might have been by choice or simple overlooking of the question(s).
2. Response was invalid, e.g. where only one answer was required but the respondent selected several responses.

Table 5-7. Formal Evaluation - Distribution of participants by age and sex.

	16-24 (total %)	25-44 (total %)	45-64 (total %)	65+ (total %)	Total	Percentage
Male (total %)	150 (32.40%)	82 (17.71%)	21 (4.54%)	6 (1.30%)	259	55,94%
Female (total %)	104 (22.46%)	64 (13.82%)	33 (7.13%)	3 (0.65%)	204	44,06%
Total	254	146	54	9	463	
Percentage	54,86%	31,53%	11,66%	1,94%		100,00%

The formal evaluation was conducted at the same place as the preliminary evaluation, Microcosm, and it was conducted over a two-month period (from April 28th to July 1st). During this period, four hundred sixty three random visitors agreed on participating in the formal evaluation, two hundred fifty nine of whom were men (55,94%). Most of the participants were from 16 to 24 years old (54,86%). All participants were random visitors of Microcosm who could speak fluently and understand the English language.

The overwhelming percentage of 80.56% of participants admitted knowing a person diagnosed with cancer (Chart 5-18). Only one third of them didn't feel comfortable enough to share more information about this topic (Chart 5-19). Almost half of the participants (45.45%) who shared information had at least one person diagnosed with cancer. In most cases, participants mentioned either a grandparent (20.91%) or a friend (20.38%) being offended by this disease. Chart 5-21 shows the three main types of relationship participants referred having with people diagnosed with cancer.

One hundred and fifty eight participants expressed with their own will some of their feeling regarding this situation, a person from their environment being diagnosed with cancer. Table 5-8 shows the most reported emotions. At the top of the list, sadness is the

most felt emotion, followed by fear and helplessness. It should not escape our notice that the entire list of mentioned emotions consists only of negative feelings.

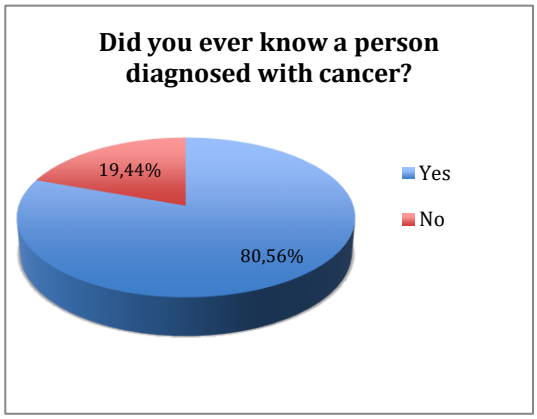


Chart 5-18. Formal Evaluation - Participants' Answers on whether they know(/knew) a person diagnosed with cancer.

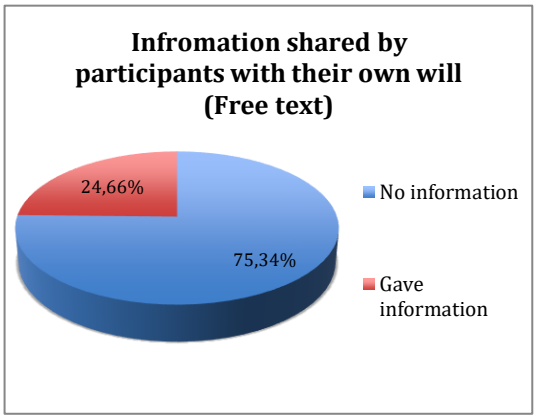


Chart 5-19. Formal Evaluation - Participants' willingness to provide more information on the people diagnosed with cancer they know(/knew).

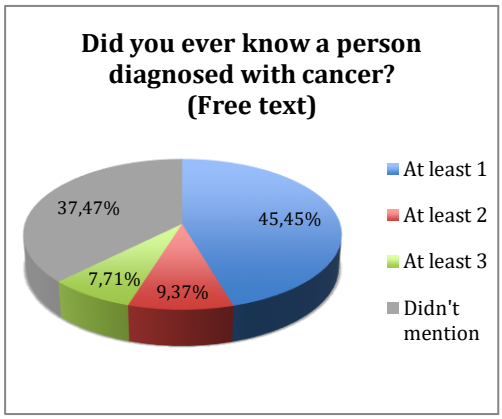


Chart 5-20. Formal Evaluation - Participants' willingness to provide more information on the people diagnosed with cancer – How many people do(/did) they know with cancer?

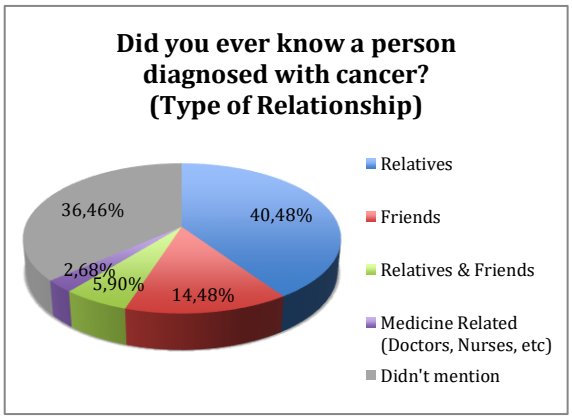


Chart 5-21. Formal Evaluation - Participants' willingness to provide more information on the people diagnosed with cancer – What type of relationship do(/did) they have with the people with cancer?

Table 5-8. Formal Evaluation - Participant's emotions for people they know(/knew) diagnosed with cancer, as expressed in their own will.

Visitors' Emotions for people diagnosed with cancer	#	Visitors' Emotions for people diagnosed with cancer	#
Sad	58	Bad	8
Afraid	13	Shocked	5
Helpless	11	Devastated	5
Not nice	10	Powerless	4
Worried	9	Upset	4

In relation to the question of how comfortable they felt when talking about cancer before playing HEAL, only 16.41% claimed feeling uncomfortable about it (Chart 5-22). The Mann-Whitney U Test also confirmed that participants who shared any kind of information regarding the people they know being diagnosed with cancer, were feeling more comfortable talking about cancer than people who chose not to share any information ($p = 0.005$).

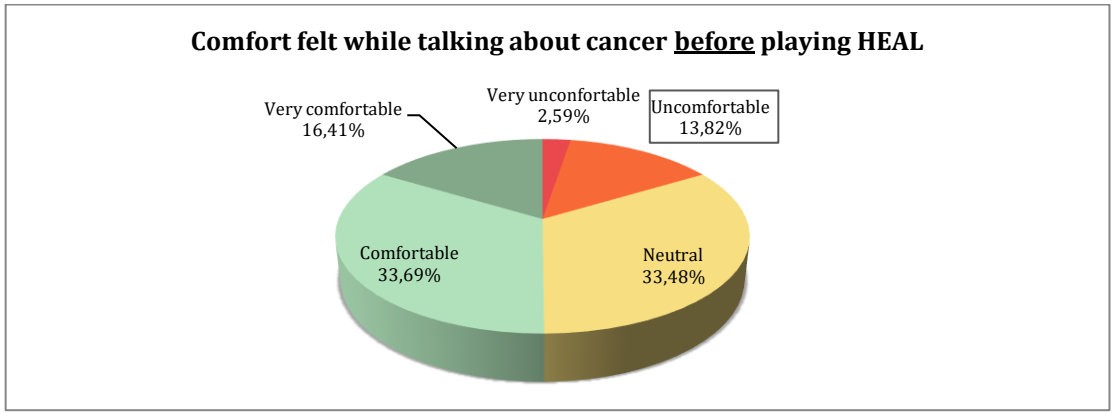
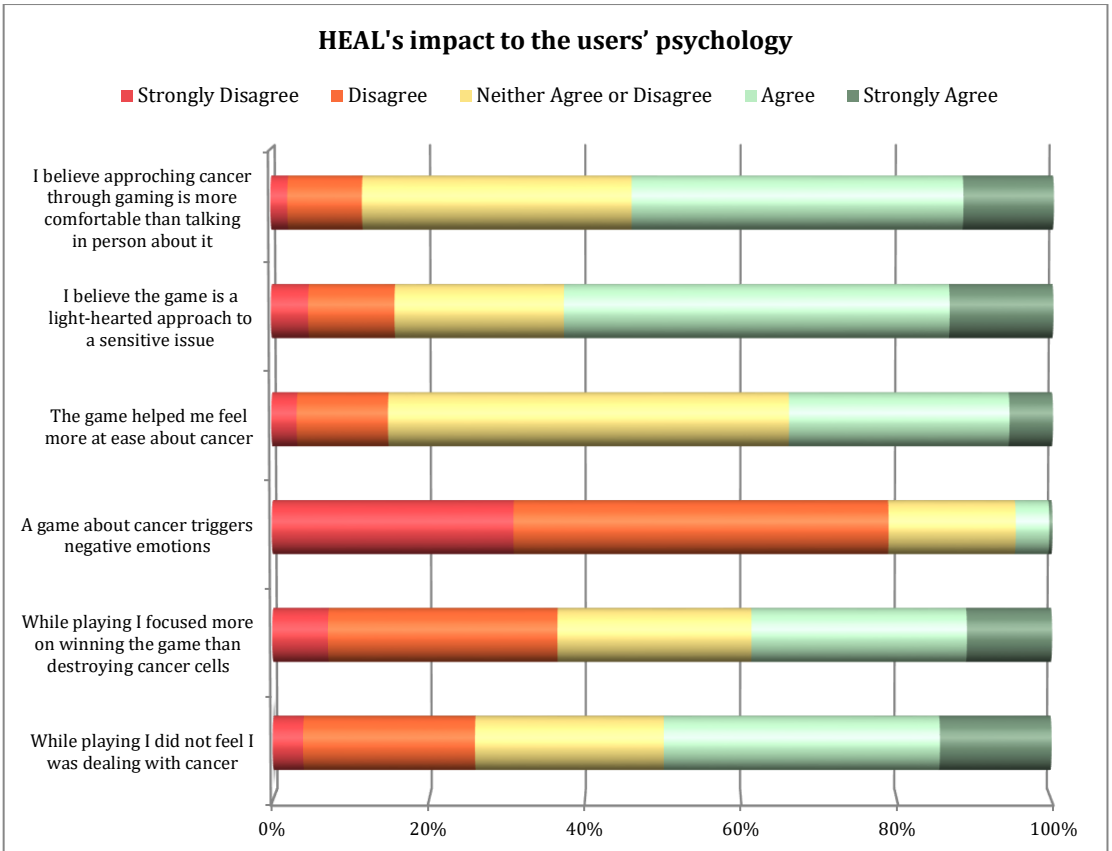


Chart 5-22. Formal Evaluation – Participant's comfort when talking about cancer before playing the HEAL game.

Chart 5-23 is an overview of the participants' answers in questions related to their frame of mind while interacting with HEAL. From a first look, one may observe that the

overall outcome is positive. In more detail, while playing almost half of the participants (49.89%) did not feel that they were dealing with cancer. While this may seem a desired result with a positive outcome, some may argue that this is a sign of disrespect as users have too much fun and forget about the game's purpose. The evaluation results have shown that there is an almost perfect balance between fun and seriousness. 36.50% claimed focusing more on destroying the cancer cells, while 38.66% mentioned focusing more on winning the game. In either case, only 4.75% believes that a game about cancer triggers negative emotions. A big portion of the participants (62.63%) expressed that the game was a light-hearted approach to a sensitive issue. One third of the participants claimed that the HEAL helped them feel more at ease about cancer, and more than half believe that approaching cancer through gaming is more comfortable than talking in person about it.



	While playing I did not feel I was dealing with cancer	While playing I focused more on winning the game than destroying cancer cells	A game about cancer triggers negative emotions	The game helped me feel more at ease about cancer	I believe the game is a light-hearted approach to a sensitive issue	I believe approching cancer through gaming is more comfortable than talking in person about it
Strongly Disagree	3,89%	7,13%	30,89%	3,24%	4,75%	2,16%
Disagree	22,03%	29,37%	47,95%	11,66%	11,02%	9,50%
Neither Agree or Disagree	24,19%	24,84%	16,41%	51,19%	21,60%	34,34%
Agree	35,42%	27,65%	4,32%	28,29%	49,24%	42,33%
Strongly Agree	14,47%	11,02%	0,43%	5,62%	13,39%	11,66%

Chart 5-23. Formal Evaluation – Participants' Answers on HEAL's impact to their psychology.

In general, results have shown that user's psychology has not been affected negatively while interacting with HEAL, even though its saddening nature. Chart 5-24 shows participants' comfort about talking for cancer after the game. One out of five participants claimed feeling more comfortable after interacting with the game. It is also worth mentioning that none of the participants mentioned feeling less comfortable after interacting with HEAL.

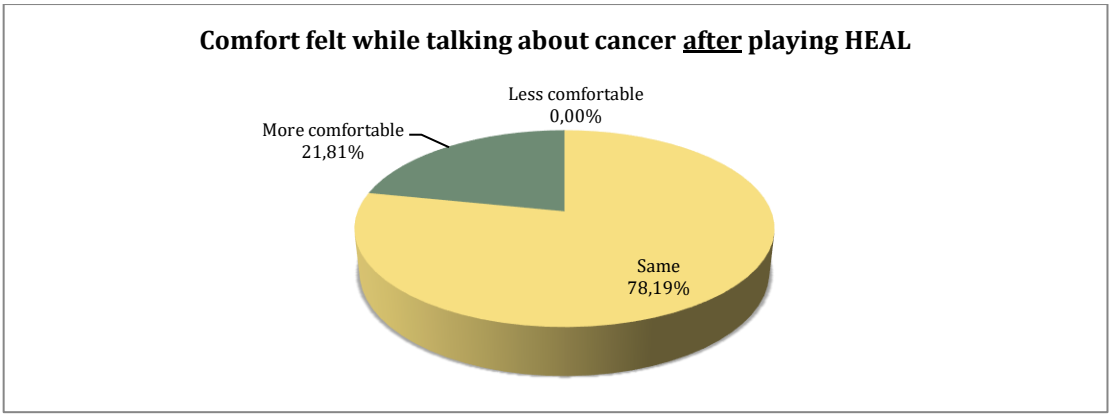


Chart 5-24. Formal Evaluation – Participant's comfort when talking about cancer after playing the HEAL game.

Regarding learnability, results were also promising. In order to evaluate the quantity and quality of information assimilated by participants, a couple of questions were added to the questionnaire related to the background knowledge they had before visiting CERN's permanent exhibition, Microcosm.

As shown in Chart 5-25, Chart 5-26 and Table 5-9, while quite more than half (67.17%) participants knew about CERN's contribution to society (e.g. WWW, Grid), only 38,88% of them had heard about proton therapy. Only three out of ten people knew both about CERN's contribution and Proton Therapy before their visit at Microcosm. Almost one fourth of the participants knew nothing about CERN's activities outside the physics field. These results prove the urgent need of informing the public about the organisation's contribution besides physics.

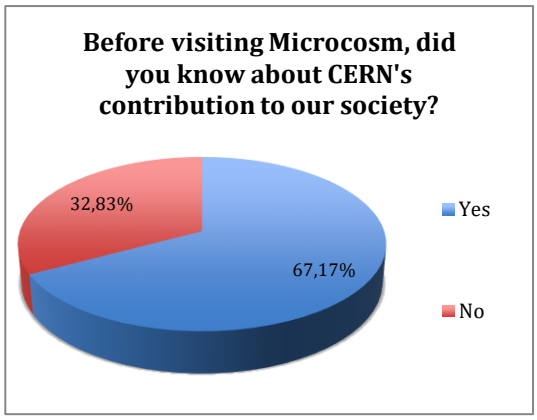


Chart 5-25. Formal Evaluation - Participants' input on their previous knowledge on CERN's contribution to society.

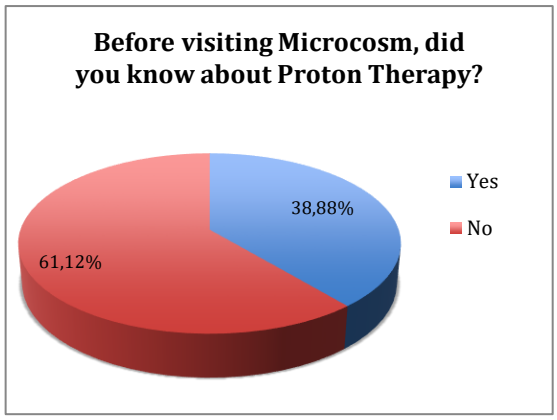
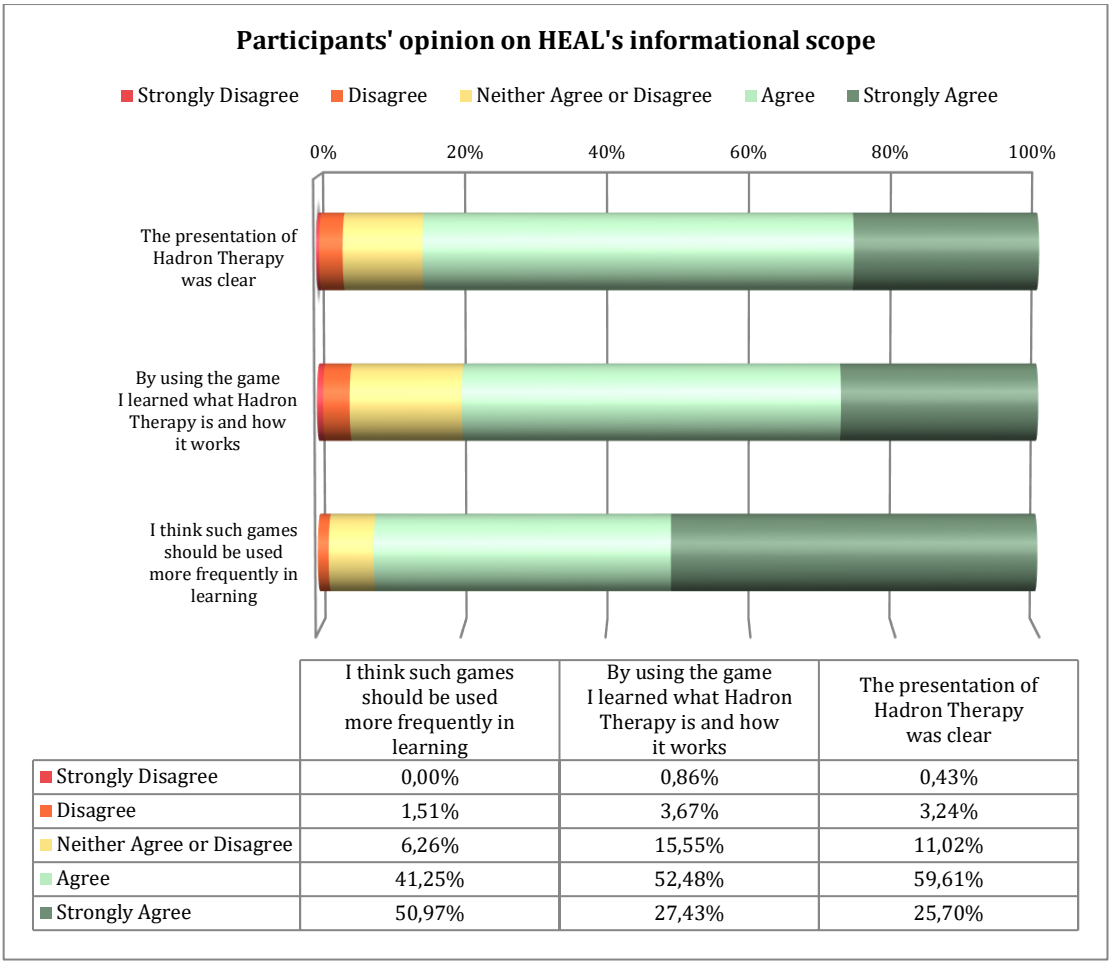


Chart 5-26. Formal Evaluation - Participants' input on their previous knowledge on Proton Therapy.

Table 5-9. Formal Evaluation - Participant's input on their previous knowledge regarding CERN's contribution to society and Proton Therapy.

Before visiting Microcosm…		Knew about Proton Therapy		Total	Percentage
		Yes (total %)	No (total %)		
Knew about CERN's contribution to society	Yes (total %)	142 (30.67%)	169 (36,50%)	311	67.17%
	No (total %)	38 (8.21%)	114 (24.62%)	152	32.83%
Total		180	283	463	
Percentage		38.88%	61.12%	100%	

After interacting with HEAL, participants were asked about the information acknowledged by using the game (Chart 5-27). Almost 80% of the participants (79.91%) claimed understanding what Hadron Therapy is and how it works by using HEAL. Only 3.67% of the participants said that the presentation of Hadron Therapy was not clear. Moreover, 92.22% suggested the more frequent use of such games in learning.



	I think such games should be used more frequently in learning	By using the game I learned what Hadron Therapy is and how it works	The presentation of Hadron Therapy was clear
Strongly Disagree	0,00%	0,86%	0,43%
Disagree	1,51%	3,67%	3,24%
Neither Agree or Disagree	6,26%	15,55%	11,02%
Agree	41,25%	52,48%	59,61%
Strongly Agree	50,97%	27,43%	25,70%

Chart 5-27. Formal Evaluation - Participants' opinion on HEAL's informational scope.

In order to evaluate whether participants expressed their honest opinion, a set of multiple choice questions have been included in the questionnaire. In this way, we can verify whether HEAL fulfilled its informational purpose and participants actually have drawn the information intended to transmit through HEAL. To eliminate random answering, in two of the three questions, a verification question was included as well asking to select a justification for participants' previous answer.

Chart 5-28 shows participants' answers in questions related to HEAL's informational purpose. From a first look one may observe that the majority of participants apprehended the information that HEAL provided them either from its gameplay metaphors (e.g. aiming, kicking, etc.), or from its graphical interface. 71.49% of the participants answered correctly in both the first question and its verification, 63.71% in

both the second question and its verification, and finally 97.41% answered correctly in the third question.

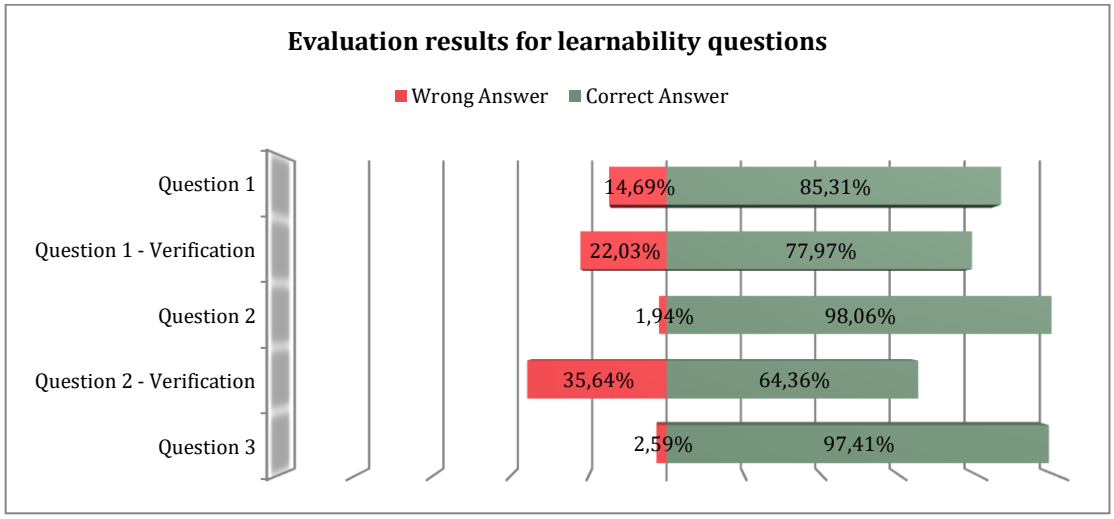
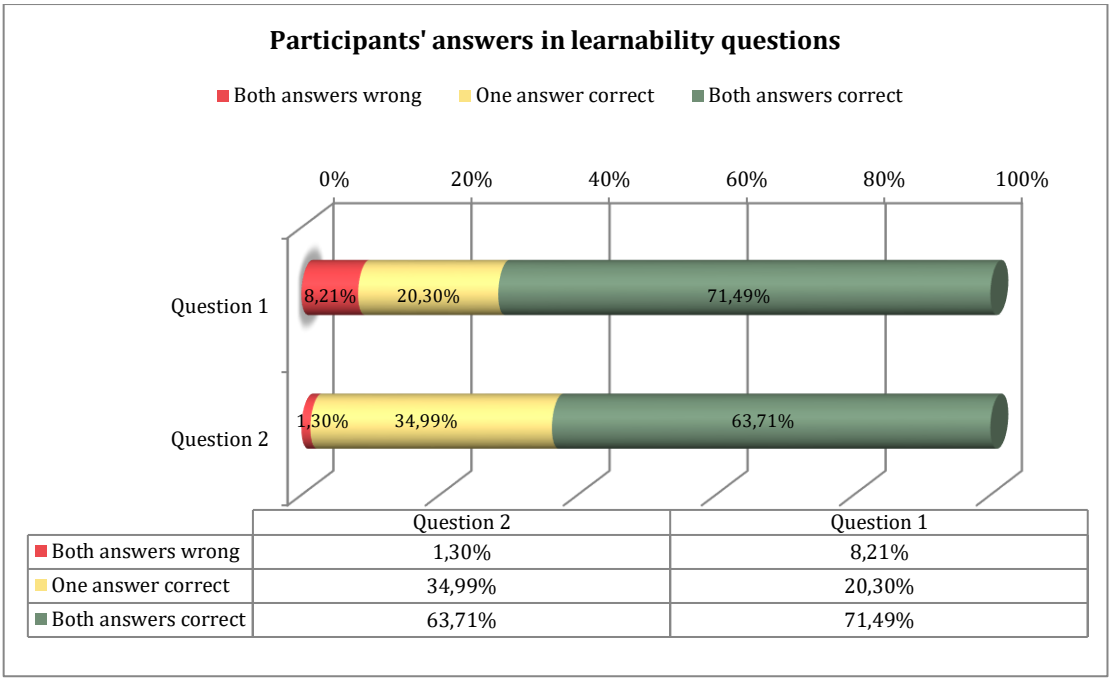


Chart 5-28. Formal Evaluation – Evaluation Results for learnability questions.

In case a participant answered a question correctly but the verification of this exact question wrongly, or in reverse, we considered the answer to that question as wrong. Chart 5-29 and Chart 5-30 show participants' answers regarding the first two questions, which also had verification questions. The number of participants having both the question and its verification wrongly answered is really small.

Having the above-mentioned assumption in mind, only four participants answered all three questions wrong (0.86%), while almost half of the participants answered all questions correctly (49.03%). Chart 5-31 shows the number of the total correct answers participants gave.



	Question 2	Question 1
Both answers wrong	1,30%	8,21%
One answer correct	34,99%	20,30%
Both answers correct	63,71%	71,49%

Chart 5-29. Formal Evaluation – Participants' answers for the first two learnability questions.

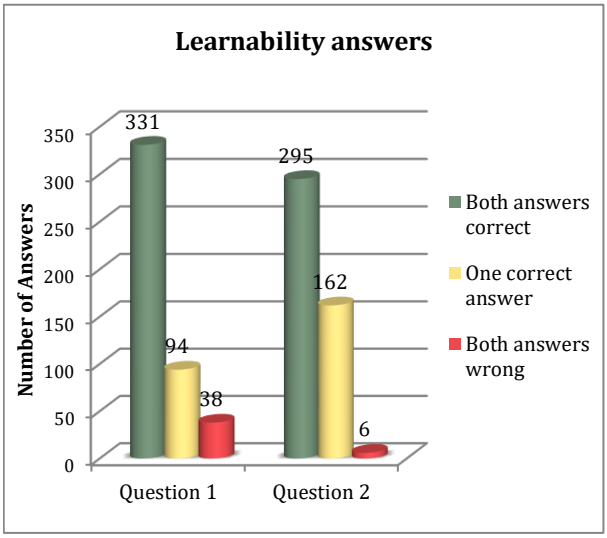


Chart 5-30. Formal Evaluation - Participants' answers in numbers for the first two learnability questions.

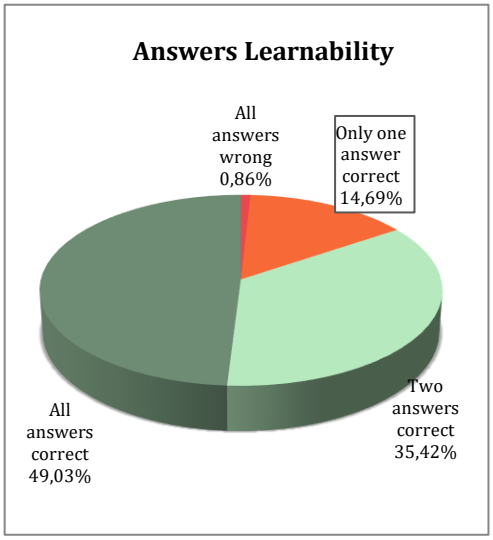


Chart 5-31. Formal Evaluation - Participants' answers in learnability questions.

Consequently, as shown by participants' answers, HEAL did fulfil its learning purpose since participants claimed of having learnt what Hadron Therapy is and how it works. This also gets verified from their correct answering in a set of learnability questions. The evaluation showed that only 11.66% of participants had a wrong perception of Hadron

Therapy. This is because although they claimed having a good understanding of what Hadron Therapy is and how it works after playing the game, they replied to more than half of the questions wrongly.

It is also worth mentioning that for a small number of participants (125 out of 463) the time spent interacting with HEAL was also documented. Chart 5-32 shows how much time participants spent using the game. It is quite impressive to mention that fifty two out of one hundred and twenty five participants answered correctly to all learnability questions by only spending no more than 30 seconds of interaction with HEAL (41.60%). This number gets much higher for participants who spent up to 60 seconds (77/125 - 61.60%). Chart 5-33 shows the number of correct answers given relatively to the time spend interacting with HEAL. While the sample not be big enough, there is a distinct trend that most users acquire the needed knowledge during their first minute of interaction with HEAL. A couple of tries with the game seem to be enough in order for participants to understand what Hadron Therapy is and how it works. This seems to be the same case even when users get the wrong perception of a game's purpose. Playing longer HEAL did not lead into users getting a clearer understanding. On the contrary, users' perception was formed during the first minute of interaction, similarly to the first case. This means that users acquire their perception during their first minute of interaction with the game, regardless of whether this is correct or not.

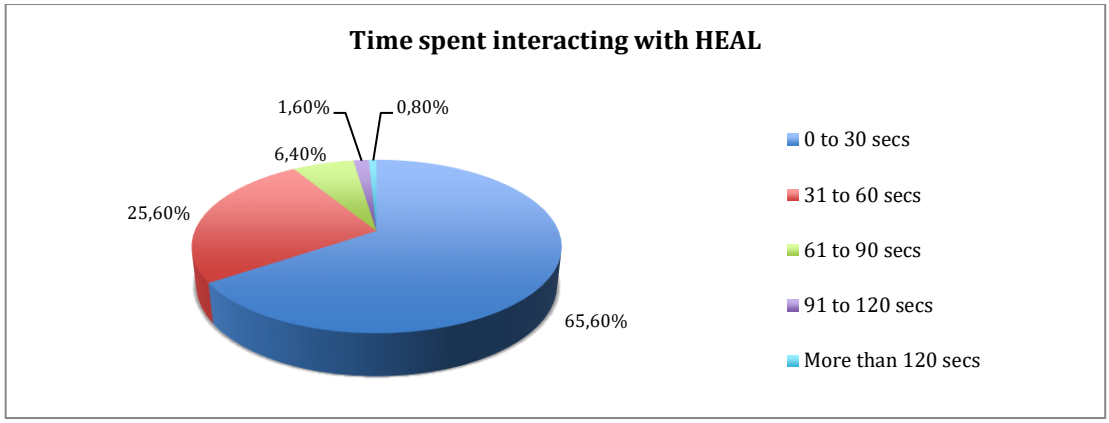
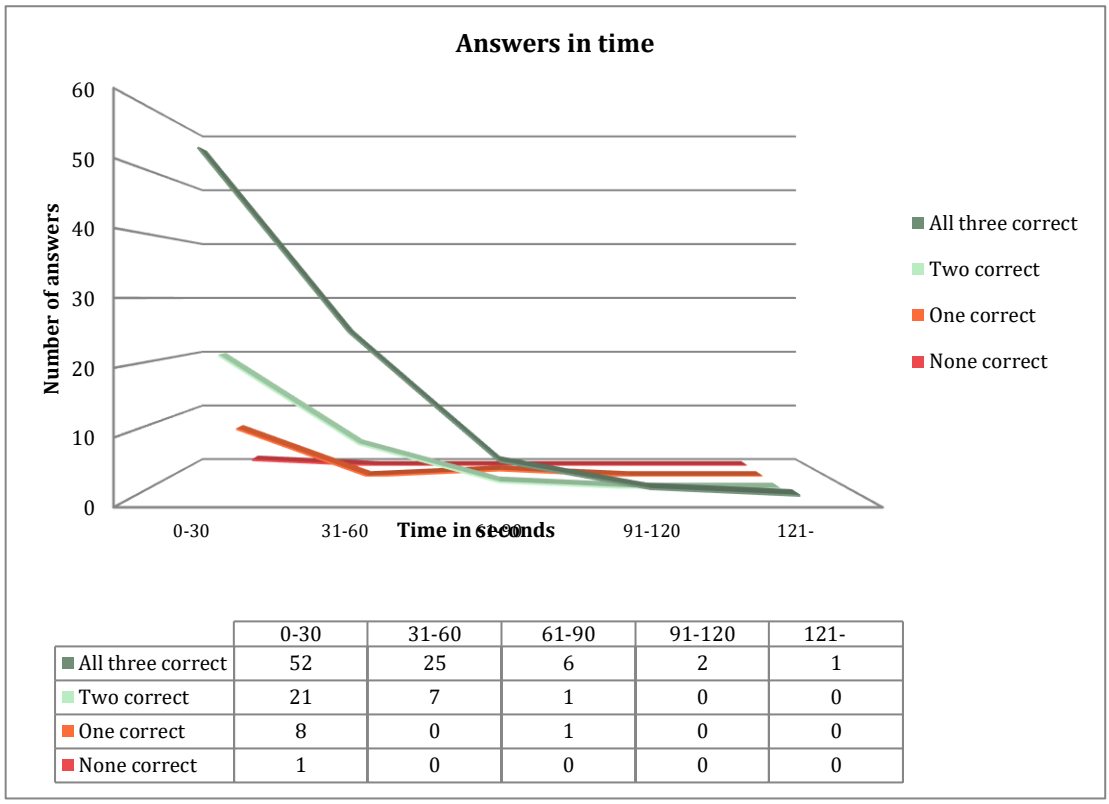


Chart 5-32. Formal Evaluation - Participants' time spent interacting with HEAL.



	0-30	31-60	61-90	91-120	121-
All three correct	52	25	6	2	1
Two correct	21	7	1	0	0
One correct	8	0	1	0	0
None correct	1	0	0	0	0

Chart 5-33. Formal Evaluation - Participants' number of correct answers given relatively to the time spend interacting with HEAL

Overall, 92.01% of the participants stated having a good experience (Good – 63.07%, Excellent – 28.94%) with HEAL.

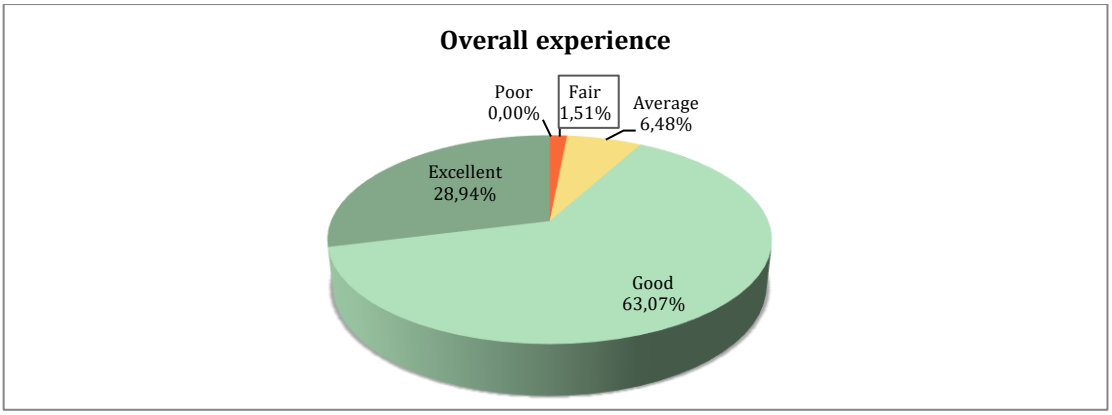


Chart 5-34. Formal Evaluation - Participants' overall experience with HEAL

5.4 Discussion

Nano-games seem to head in the right direction as HEAL's evaluation showed some promising results when put under the pressure of loads of visitors. CERN's Microcosm has 400 visitors in average per day and its open for 9 hours on working days, and for 8 hours on Saturdays. It is quite common for more than 5 people (even 20) arriving at the same time and, since a visit lasts approximately 1.5 hours, they only spend a few minutes at one exhibit. Since the majority of the visitors have never visited CERN before and one fourth of its visitors has no knowledge about CERN's activities outside the physics field, the challenge to deliver the main message(s) gets even more elusive. This can be feasible with nano-games. Doing some simple calculations, on a working day having 400 visitors, each one can play HEAL spending 1 minute and 21 seconds. Having in mind the evaluations' results, 1:20 minutes is more than enough for a visitor to get the main message(s) that the nano-game is willing to pass to its players. This is verified by the fact that participants who agreed that the hadron therapy presentation was clear also responded correct to all learnability questions ($\chi^2(12)=44.547$, p=0).

In addition to the above, a MIO can have more than one nano-games. Since its purpose is fulfilled in a matter of seconds, visitors can play a number of nano-games and acquire in a playful way the needed information they were seeking for. This would not be possible with games that last tens of minutes or even need training in order to be played. As already presented in [75], micro-games are described as a "*means to reinforce and integrate part of the knowledge learnt in the expository lecture*" and are lectures' supplements. For their evaluation, students from four high schools participated answering a) an immediate post-questionnaire, and b) a one month delayed post-questionnaire. The full questionnaires were not available in [75]. Results seemed encouraging as the micro-game was at least as effective as traditional instruction, when measured immediately after the exposure and reinforced and integrated knowledge was retained better. On the other hand however, nano-games are presented as an independent, self-contained approach, with no need for introduction or briefing, either before of after their use. While an info-box was available, it does not imply that users actually took the time to read it, as no data were collected to this end. In addition to the above, our evaluation took place in an international organisation, CERN, visited by a high variety of visitors in the terms of several aspects such as sex, gender, nationality, background knowledge, etc. The formal evaluation showed that 350 out of 463 (75.59%) participants come from countries outside Switzerland, France, Germany, Italy and Austria to visit CERN. As a result, one can assume that due to the long-distance limitation, visitors are not able to revisit often. This, along with the anonymity of the questionnaires, makes the possibility of post-questionnaires for our evaluation unattainable.

By playing HEAL we believe that, apart from finding out about a quite new cancer therapy that most people do not even know it exists, a wide variety of users' questions can be answered. For example, some questions include "what hadron therapy is and how it works", "why prefer it to some other treatment", "what is the connection between

CERN and medicine", "how can CERN be related to other research fields that seem to be irrelevant", and "how technologies developed at CERN can be affect our everyday life". HEAL's evaluation showed that more than half of the visitors (61.60%) who spent no more than a minute interacting with the nano-game, were able to answer correctly to some learnability questions. The questions were targeted to HEAL's messages to pass, accompanied with justification questions in order to eliminate randomised answering.

The first statement participants were asked to agree or not, was "Protons used in proton therapy destroy everything in their way, until the moment they stop." (Correct Answers: "Disagree" – "Selecting the correct energy"). To answer correctly this question and its verification question, participants need to first be able to answer the following questions: "what hadron therapy is and how it works" and "why prefer it to some other treatment". As described in paragraph 4.1.2 in Proton Therapy machines are used to direct radiation to the tumour. By controlling the amount of energy given to the protons, one can determine the depth in which they penetrate. Also, due to the Bragg Peak degradation, Proton Therapy causes less damage to healthy tissue than Conventional Radiation Therapy. In HEAL, users need to adjust the energy in order to control protons' penetration depth. If a user selects the maximum possible energy, the cancer cells located in the proton beam's direction will not be affected. This will not happen if the amount of energy is carefully selected for the beam to stop exactly at the depth the cancer cells are located.

The second statement participants were asked to agree or not, was "Proton therapy uses accelerator technologies derived from CERN research." (Correct Answers: "Agree" – "The graphics on the floor"). To answer correctly this question and its verification question, participants need to first be able to answer the following questions: "what is the connection between CERN and medicine", "how can CERN be related to other research fields that seem to be irrelevant", and "how technologies developed at CERN

can be affect our everyday life". Throughout the gameplay, HEAL users are asked to physically kick for the proton beam to start accelerating. A CERN accelerator is visible on HEAL's "Floor" side, showing the accelerating particles which are later transferred to the "Wall" side and then irradiated to the humanoid's head.

The last statement participants were asked to agree or not, was "CERN has no relation with medicine." (Correct Answer: "Disagree"). Similarly to the second statement, participants needed to be able to answer the same set of questions in order to correctly answer this statement.

For participants answering correctly to all learnability questions, we believe that learning has occurred as they were able to note the general idea behind the nano-game they interacted with, as asserted by Falk and Dierking [15].

Another aspect that had not been mentioned above could be the cost of developing a nano-game. Nano-games are self–contained games of a single level of difficulty, contrary to other games where more than one difficulty levels are available. Usually, small MIOs do not have the economic vigour (e.g. human resources) to fund expensive games. Nano-games offer the alternative of an inexpensive, yet qualitative implementation since due to their shortness and simplicity, one does not need to develop as much as they would when developing a multilevel game.

Finally, during our evaluation there were a few cases where visitors had physical disabilities, either temporary (broken arm or leg) or permanent (paralysed hand or leg). In case one of their hands was functional, visitors were able to play the game with no issues by using only one hand for both controllers. There were also cases where visitors would use a wheelchair. HEAL was able to identify the user and, albeit the user was not able to physically kick, just by moving the wheelchair forward they were able to simulate the "kick" gesture and be able to play. Such cases are not seldom as recent

statistics on the situation of people with disabilities in the European Union showed that 14% of people aged 15-64 report a basic activity difficulty (e.g. walking, hearing, seeing) [122]. With one out of seven people having a disability, we believe that there is an evident need for looking more into how nano-games using body gestures as controllers respond in such cases. Even though HEAL responded well for people with disabilities and is optimistic, we believe that the cases we had are not enough to draw conclusions, so we leave it as future work.

Based on our evaluation, we claim that HEAL follows the Seven Principles of Universal Design as developed in 1997 by a team led by the late Ronald Mace [123]. These principles guide the design process and educate both designers and consumers about the characteristics of more usable products and environments. HEAL offers:

1. **Equitable Use**, as all visitors regardless of their origin, age, background or skills could successfully use the nano-game and achieve its goal.
2. **Flexibility in Use**, since visitors could use either or even both of their hands and feet to operate the game, at their pace.
3. **Simple and Intuitive Use**, considering the feedback received from the evaluation participants.
4. **Perceptible Information**, since clear and understandable instructions were provided to HEAL users. Also, the main message of the game was communicated correctly to most of its users.
5. **Tolerance for Error**, as in case a player failed to achieve the goal (destroy cancer cells) the humanoid patient would not get harmed and the player was able to try again.
6. **Low Physical Effort**, considering HEAL exploits the mechanics of well-known and popular games as well as user's biologically primary knowledge.

7. **Size and Space for Approach and Use**, since users can use it regardless of their body size, posture, or mobility. Yet, as mentioned before, further evaluation is suggested for people with disabilities.

5.5 Limitations & Future Work

We believe that nano-games offer MIOs the opportunity to provide a fast, yet qualitative informational experience to their visitors. Regardless of their shortness in time or of the crowds that may exist, especially in peak hours, visitors are able to get the maximum interactive experience possible in a matter of seconds. Moreover, MIOs ensure that every visitor leaves their venue with an understanding of what they wished to communicate through a fun medium. For a MIO like CERN, where the exhibitions have a strong basis on physics, full-body interactive nano-games can offer a viable approach to help convey the message to the visitors.

However, one could envisage the usage of nano-games in the context of other types of MIOs, in fields other than physics. For example, nano-games could be exploited in history of sports museums to offer insights on games mechanics or ergonomics. Another example could be in a geology museum to help understand the pressure and heat required to create a diamond.

Working in a real life setting in a crowded venue like CERN, we had to respect organisational issues and not interrupt the visitor flow. For this reason, we proceeded with a grab sampling process. This type of sampling process, being non-probability, implies that it is more flexible in a real venue setting, but it also means that we cannot easily generalise the findings. Keeping these in mind, the nevertheless strongly significant results of the present work, can be read as strong indicators of possible

tendencies. However, the present work also used a rather large sample (N=463) to increase the reliability of its findings.

In the near future we are planning to test the suitability of nano-games to other more traditional MIOs, especially museums and cultural venues. We foresee that, depending on the MIO, special effort may be required to identify the main message(s) to be conveyed through the nano-game and design nano-games that manage to communicate the message to the visitors. Also, we are looking into using small demo videos or animations, instead of images, on how to play the nano-games. The demo videos will be automatically triggered as soon as a visitor enters the interactive space aiming to attract her to play the game.

6 Discussion

As MIOs seek to attract and engage more visitors, they need to find ways to understand visitor expectations and experiences, and be responsive to a variety of interests and needs. In addition, MIOs need to ensure that every visitor leaves with an understanding of the basic message(s) the exhibition wishes to communicate. MIOs have reverted to the development of interactive content in an effort to provide information in a playful and engaging way.

A major obstacle in efficiently communicating the exhibition's message(s) is that of the restricted visiting time. Research has shown that MIO visitors spend no more than 90 minutes in exhibitions [12, 21-26], and at most 2 minutes [27, 28] in front of an exhibit. This is more challenging when visitors are part of a group visit when they have to go with the flow of the group and follow a schedule. Also, it is not unusual that group's points of interest are not of the same importance for all of its members. This can lead to skipping exhibits in order to gain time and get back to schedule for the group's agenda.

Existing approaches, even though promising, require user profiling obtained by either questionnaires or observation. In the case of questionnaires, visitors are not always willing to provide the time or information needed, especially when they are part of a group visit. On the other hand, observation needs enough data to be collected in order for a user profile to be formed.

To this end, we suggested a holistic approach on exploiting all phases of visitors' time before (Phase A), during (Phase B) and after their visit (Phase C) in order to provide a better and more personalised Quality of Experience (QoE). We viewed Phases A and C as an extension of the actual visit and an opportunity to better identify visitor's needs and offer a post visit experience, as described in Chapter 2, For Phase B, as described in Chapter 3, we proposed nano-games to be used during one's visit in an effort to communicate in a fun way the MIOs main message(s) quickly.

To evaluate our proposal, two approaches, named "My Museum Experience" and "HEAL" were developed. "My Museum Experience" is a Visit Elongation component bundle exploiting Social Media games to form user profiles that are later used to the actual MIO visit, as well as attract new MIO visitors. "HEAL" is a Message Passing nano-game aiming to communicate correctly a MIO's message within tens of seconds.

Evaluations took place in modern, cutting-edge MIO's, in order to assess whether the proposed approach could be followed in spaces other than conventional museums. Chapters 2.4.5 and 5.3 describe the followed procedure and analyse all participants' answers. All evaluations showed promising results with the most important ones being:

- Social Media games can reveal cognitive styles. Users' choices throughout the gameplay reveal their personal interests.
- Nano-games can pass basic messages in a fast and fun way, regardless of users' experience.

Even though a MIO can adopt either of the *Visit Elongation* or the *Message passing* approach, we believe that a combination of the two will provide the most beneficial results. MIOs can have a "My Museum Experience" component bundle, as well as several

nano-games available in their exhibition. In a case scenario when one is to visit a MIO in the next month as part of a group visit, their schedule is predefined by the group and their time will be limited. Assuming they are aware of the MIOs Social Game ("My Museum Story"), they would interact with it before their visit. The derived user profile would be ready to use once they visit the MIO. Fast-forward to a month after, when the visit happens, the MIO's recommendation engine ("My Museum Guide") would show personalised information and recommendations to the visitor, that may include playing one or more nano-games, depending on the game's basic message and the user's preferences. During or after their visit, users can share their experience to their Social Media acquaintances, keeping the interest alive while attracting more people to the MIO.

Evaluation has also showed promising results for people with disabilities, even though a more targeted evaluation should be held, especially in the terms of nano-games.

We are confident that our approach can effectively overcome the issue of visitors leaving MIOs unsatisfied of their experience and with no understanding of the MIO's basic message(s). We believe that our approach can be adopted by any MIO, regardless its size or topic. Guidelines presented in this thesis can be adapted to each MIOs needs in order to create a "My Museum Experience" component bundle and/or one or more nano-games. Nano-games could also be used in education (schools, universities, etc) in order to provide a fast and fun way for students to acquire difficult concepts in a short period of time.

Limitations such as visitors not having access to the technology or equipment needed to follow this approach can be addressed from MIOs themselves, by providing smartphones or tablets to their visitors in order to access the "My Museum Experience" component bundles, returned to the venues after their visit. Nano-games' cost can be reduced by using one TV/screen and by avoiding the use of controllers, as they can be prone to breaking due to heavy use.

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Appendix

I. Cover Letter

SURVEY

"Impact of Games on Serious Health Diseases"

Dear Participant,

My name is Jenny Rompa and I am a Doctoral student at CERN coming from the University of Peloponnese. For my doctoral dissertation, I am examining the experience users acquire from interacting with games related to serious health diseases. **Because you played the "HEAL" game**, I am inviting you to participate in this research study by completing the attached survey.

The following questionnaire will require approximately 2 minutes to complete. There is no compensation for responding nor is there any known risk. In order to ensure that all information will remain confidential, please do not include your name. **All of the response in the survey will be recorded anonymously and be strictly used for scientific purposes only.** Copies of the project will be provided to my CERN and University of Peloponnese instructors as well to the Ph.D. committee that will conduct the qualifying examination. If you choose to participate in this project, please answer all questions as honestly as possible and return the completed questionnaires promptly to me. **Participation is strictly voluntary and you may refuse to participate at any time.**

Thank you for taking the time to assist me in my educational endeavours. The data collected will provide useful information regarding the evaluation research to be conducted. Completion and return of the questionnaire will indicate your willingness to participate in this study. If you require additional information or have questions, please contact us at the.heal.game@cern.ch.

Sincerely,

Jenny Rompa

Doctoral Student at CERN

II. Questionnaire 1 of Preliminary Evaluation

1. Tell us a little bit about yourself

   A. You are: ☐☐ Male ☐ ☐ Female

   B. What age group do you fall into? ☐☐ 16-24 ☐ ☐ 25-44 ☐ ☐ 45-64 ☐☐ 65+

   C. Your country of birth: _____

2. With whom are you visiting this museum today?

   ☐☐ Alone ☐☐ Partner ☐☐ Family (including children aged under 16)

   ☐☐ Friends ☐☐ School Party ☐☐ Organised Group ☐ Other: _____

3. Approximately how far did you travel to get here today?

   ☐☐ Less than 5 kilometres ☐ 5-20 kilometres ☐ 20-50 kilometres

   ☐☐ 50-100 kilometres ☐☐ More than 100 kilometres ☐☐ Don't know

4. What is the main purpose of your visit? Please select all that apply.

   ☐☐ Education ☐☐ Entertainment ☐☐ Work ☐ Other: _____

5. A. Is this your first time using this game? ☐☐ Yes ☐☐ No

   B. If not your first time, including today, how many times have you used the game? _____

6. A. How did you first find out about this game?

   ☐☐ From friends/ relatives ☐☐ Media - Social Media

   ☐☐ Noticed it in passing ☐ Other: _____

   B. In case you found out from friends/relatives, do/did they have any connection with CERN?
   ☐☐ Yes ☐ ☐ No

7. Please select the box that corresponds to your answer regarding **your game experience**.

	Strongly Disagree	**Disagree**	**Neither Agree or Disagree**	**Agree**	**Strongly Agree**

	Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
The game was fun to use	☐	☐	☐	☐	☐
The game was childish	☐	☐	☐	☐	☐
The game held my interest throughout its use	☐	☐	☐	☐	☐
The game was still fun to play after one try	☐	☐	☐	☐	☐
The game was easy to win	☐	☐	☐	☐	☐
The goal of the game was clear	☐	☐	☐	☐	☐
I would like to play the game again	☐	☐	☐	☐	☐
I would recommend this game to a friend	☐	☐	☐	☐	☐
I would like to share my time score on Social Media (e.g. Facebook, Twitter, Google+)	☐	☐	☐	☐	☐
While playing I forgot about everything else	☐	☐	☐	☐	☐
I felt absorbed by the game	☐	☐	☐	☐	☐
I was interested in seeing how the games' events would progress	☐	☐	☐	☐	☐
I was in suspense about whether I would win or lose the game	☐	☐	☐	☐	☐
There were times when I wanted to give up playing	☐	☐	☐	☐	☐
I would have loved to play longer	☐	☐	☐	☐	☐
By using the game I learned what Hadron Therapy is and how it works	☐	☐	☐	☐	☐
I enjoy learning in this environment	☐	☐	☐	☐	☐
I could learn more in this environment	☐	☐	☐	☐	☐
The game enhanced my learning process	☐	☐	☐	☐	☐
I was supported positively from my peers	☐	☐	☐	☐	☐
I think such games should be used more frequently in learning	☐	☐	☐	☐	☐
The scope of the game was clearly understood	☐	☐	☐	☐	☐
The presentation of Hadron Therapy was clear	☐	☐	☐	☐	☐
The game enhanced my exhibition visit	☐	☐	☐	☐	☐
The technology used (sensors, animation, graphics, sound) contributed to the learning process	☐	☐	☐	☐	☐
The game wouldn't be that fun if I were using an input device (e.g. mouse, keyboard, joystick) to control it.	☐	☐	☐	☐	☐
Such games should be used to supplement traditional learning approaches	☐	☐	☐	☐	☐
The graphics used in the game are appropriate	☐	☐	☐	☐	☐
When I came in, I was not interested in CERN	☐	☐	☐	☐	☐
After playing, I want to learn more about science	☐	☐	☐	☐	☐
After playing, I want to learn more about CERN technologies	☐	☐	☐	☐	☐
After playing, I want to learn more about hadron therapy	☐	☐	☐	☐	☐
I have a strong experience playing with Wii or X-Box Kinect	☐	☐	☐	☐	☐

8. HEAL is a single player interactive game. In a hypothetical scenario, which case do you think would be **the most entertaining to use**?

   ☐☐ Single Player Game/Player against cancer (Current Game Scenario)

   ☐☐ Two-Player Game/Competing against a friend. The one who vanishes cancer faster, wins.

   ☐☐ Two-Player Game/Cooperating with a friend. Attacking cancer by using two gantries instead of one.

   ☐☐Multi-Player Game (More than 2)/Competing with friends through publishing scores on Social Media (e.g. Facebook, Twitter, Google+). The one who vanishes cancer faster, wins.

   ☐☐ Multi-Player Game (More than 2)/Cooperating with more than one friends at the same time and space.

   ☐☐ Other: _____

9. HEAL is a single player interactive game. In a hypothetical scenario, which case do you think would **describe better how hadron therapy works**?

   ☐☐Single Player Game/Player against cancer (Current Game Scenario)

☐☐Two-Player Game/Competing against a friend. The one who vanishes cancer faster, wins.

☐☐Two-Player Game/Cooperating with a friend. Attacking cancer by using two gantries instead of one.

☐☐Multi-Player Game (More than 2)/Competing with friends through publishing scores on social media (e.g. Facebook, Twitter, Google+). The one who vanishes cancer faster, wins.

☐☐Multi-Player Game (More than 2)/Cooperating with more than one friends at the same time and space.

☐☐Other: _____

10. What do you particularly like about this game?

_____

_____

11. What aspects do you think need to be improved?

_____

_____

12. How would you rate your overall experience?

☐☐ Poor ☐☐ Fair ☐☐ Average ☐☐ Good ☐☐ Excellent

III. Questionnaire 2 of Preliminary Evaluation

1. Tell us a little bit about yourself

A. You are: ☐☐ Male ☐☐ Female

B. What age group do you fall into? ☐☐ 16-24 ☐☐ 25-44 ☐☐ 45-64 ☐☐ 65+

C. Your country of birth: _____

2. With whom are you visiting this museum today?

☐☐ Alone ☐☐ Partner ☐☐ Family (including children aged under 16)

☐☐ Friends ☐☐ School Party ☐☐ Organised Group ☐ Other: _____

3. Approximately how far did you travel to get here today?

☐☐ Less than 5 kilometres ☐ 5-20 kilometres ☐ 20-50 kilometres

☐☐ 50-100 kilometres ☐ More than 100 kilometres ☐ Don't know

4. What is the main purpose of your visit? Please select all that apply.

☐☐ Education ☐☐ Entertainment ☐☐ Work ☐ Other: _____

5. A. Is this your first time using this game? ☐☐ Yes ☐☐ No

B. If not your first time, including today, how many times have you used the game? _____

6. A. How did you first find out about this game?

☐☐ From friends/ relatives ☐☐ Media - Social Media

☐☐ Noticed it in passing ☐☐Other:

_____

B. In case you found out from friends/relatives, do/did they have any connection with CERN?

☐☐ Yes ☐☐ No

7. Please select the box that corresponds to your answer regarding **your game experience**.

	Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
The game was easy and simple to use	☐	☐	☐	☐	☐
Using the game was effortless	☐	☐	☐	☐	☐
I could play the game without instructions	☐	☐	☐	☐	☐
I didn't notice any inconsistencies while using it	☐	☐	☐	☐	☐
I could recover from mistakes (e.g. wrong amount of energy or direction) quickly and easily	☐	☐	☐	☐	☐
I could use it successfully (vanishing cancer) every time	☐	☐	☐	☐	☐
I found the game unnecessarily complex	☐	☐	☐	☐	☐
I found the game difficult to operate	☐	☐	☐	☐	☐
I felt confident operating the game	☐	☐	☐	☐	☐
I found the game tiring to operate	☐	☐	☐	☐	☐
There were times when I wanted to give up playing the game	☐	☐	☐	☐	☐
I think other users would like it	☐	☐	☐	☐	☐
I learned to play the game quickly	☐	☐	☐	☐	☐
I easily memorised how to play	☐	☐	☐	☐	☐
It was easy to learn to play	☐	☐	☐	☐	☐
I quickly became good at it	☐	☐	☐	☐	☐
I needed to learn a lot of things before I could play	☐	☐	☐	☐	☐
The controls of the game were difficult to understand	☐	☐	☐	☐	☐
The game presented information in an understandable manner	☐	☐	☐	☐	☐
The game clearly provided feedback about my actions	☐	☐	☐	☐	☐
It was hard to know what to do in the game	☐	☐	☐	☐	☐
I got distracted by stuff on the wall side and floor side to look at	☐	☐	☐	☐	☐
I often did not know if I would have to look at the wall side or floor side	☐	☐	☐	☐	☐
I enjoyed playing the game	☐	☐	☐	☐	☐
I would have loved to play longer	☐	☐	☐	☐	☐
The game was easy to win	☐	☐	☐	☐	☐
The goal of the game was clear	☐	☐	☐	☐	☐
I would like to play the game again	☐	☐	☐	☐	☐
I have a strong experience playing with Wii or X-Box Kinect	☐	☐	☐	☐	☐

8. What do you particularly like about this game?

_____

_____

9. What aspects do you think need to be improved?

_____

_____

10. How would you rate your overall experience?

☐☐ Poor ☐☐ Fair ☐☐ Average ☐☐ Good ☐☐ Excellent

IV. Questionnaire 3 of Preliminary Evaluation

1. Tell us a little bit about yourself

   A. You are: ☐☐ Male ☐☐ Female

   B. What age group do you fall into? ☐☐ 16-24 ☐☐ 25-44 ☐☐ 45-64 ☐☐ 65+

2. With whom are you visiting this museum today?

   ☐☐ Alone ☐☐ Partner ☐☐ Family (including children aged under 16)

   ☐☐ Friends ☐☐ School Party ☐☐ Organised Group ☐ Other: _____

3. Please select the box that corresponds to your answer regarding **your game experience**.

	Strongly Disagree	**Disagree**	**Neither Agree or Disagree**	**Agree**	**Strongly Agree**
I felt that by letting the cancer spread, I would harm someone	☐	☐	☐	☐	☐
The game's graphics helped me not feeling emotionally attached to the patient I was treating	☐	☐	☐	☐	☐
I felt responsible for curing the patient	☐	☐	☐	☐	☐
I felt happy for healing cancer	☐	☐	☐	☐	☐
I felt a sense of satisfaction and achievement	☐	☐	☐	☐	☐
While playing, I got upset	☐	☐	☐	☐	☐
While playing, I had periods of irritability or anger	☐	☐	☐	☐	☐
While playing, I sometimes got sad	☐	☐	☐	☐	☐
While playing, I felt confident about facing cancer	☐	☐	☐	☐	☐
While playing, I felt like I was harming the patient	☐	☐	☐	☐	☐
While playing, I felt like I was helping the patient	☐	☐	☐	☐	☐
While playing, I felt afraid	☐	☐	☐	☐	☐
While playing, I felt powerful	☐	☐	☐	☐	☐
While playing, I felt despaired	☐	☐	☐	☐	☐
While playing, I sometimes got stressed	☐	☐	☐	☐	☐
After playing the game, I feel strong(er) against cancer	☐	☐	☐	☐	☐
After playing the game, I feel hopeful about the future	☐	☐	☐	☐	☐
After playing the game, I feel optimistic	☐	☐	☐	☐	☐
Dealing with cancer triggered negative emotions	☐	☐	☐	☐	☐

4. The following statements concern your perception about yourself in a variety of situations. **There are no "right" or "wrong" answers, so select the number that most closely reflects you on each statement.** Take your time and consider each statement carefully.

	Strongly Disagree	**Disagree**	**Agree**	**Strongly Agree**
I have a rich vocabulary	☐	☐	☐	☐
I have a vivid imagination	☐	☐	☐	☐
I have excellent ideas	☐	☐	☐	☐
I am quick to understand things	☐	☐	☐	☐
I use difficult words	☐	☐	☐	☐
I am full of ideas	☐	☐	☐	☐
I am not interested in abstractions	☐	☐	☐	☐
I have difficulty understanding abstract ideas	☐	☐	☐	☐

	Strongly Disagree	Disagree	Agree	Strongly Agree
I have emotional intelligence	☐	☐	☐	☐
I am always prepared	☐	☐	☐	☐
I pay attention to details	☐	☐	☐	☐
I get chores done right away	☐	☐	☐	☐
I like order	☐	☐	☐	☐
I follow a schedule	☐	☐	☐	☐
I am exacting in my work	☐	☐	☐	☐
I leave my belongings around	☐	☐	☐	☐
I make a mess of things	☐	☐	☐	☐
I shirk my duties	☐	☐	☐	☐
I have high energy	☐	☐	☐	☐
I talk more than listen.	☐	☐	☐	☐
I think out loud	☐	☐	☐	☐
I think, then act	☐	☐	☐	☐
I like to be around people a lot	☐	☐	☐	☐
I prefer to work behind the scenes	☐	☐	☐	☐
I can be easily distracted	☐	☐	☐	☐
I prefer to do lots of things at once	☐	☐	☐	☐
I am outgoing and enthusiastic	☐	☐	☐	☐
I am interested in people	☐	☐	☐	☐
I sympathize with others' feelings	☐	☐	☐	☐
I have a soft heart	☐	☐	☐	☐
I take time out for others	☐	☐	☐	☐
I make people feel at ease	☐	☐	☐	☐
I am not really interested in others	☐	☐	☐	☐
I insult people	☐	☐	☐	☐
I am easily disturbed	☐	☐	☐	☐
I change my mood a lot	☐	☐	☐	☐
I get irritated easily	☐	☐	☐	☐
I get stressed out easily	☐	☐	☐	☐
I get upset easily	☐	☐	☐	☐
I have frequent mood swings	☐	☐	☐	☐
I worry about things	☐	☐	☐	☐
I am relaxed most of the time	☐	☐	☐	☐
I seldom feel blue	☐	☐	☐	☐

V. Formal Evaluation Questionnaire

1. Tell us a little bit about yourself

   A. You are: ☐☐ Male ☐☐ Female

B. What age group do you fall into? ☐☐ 16-24 ☐☐ 25-44 ☐☐ 45-64 ☐☐ 65+

C. Your country of birth: _____

2. **Before visiting Microcosm**, did you know about CERN's contribution to our society (e.g. WWW, Grid, etc.)?
☐☐ Yes ☐ ☐ No

3. **Before visiting Microcosm**, did you know about proton therapy? ☐☐ Yes ☐ ☐ No

4. A. Did you ever know a person diagnosed with cancer? ☐☐ Yes ☐ ☐ No

B. If yes, please tell us more (e.g. who, how did you feel, etc.):

_____
_____

5. How comfortable did you feel talking about cancer **before playing the game**?

☐☐ Very Uncomfortable ☐☐ Uncomfortable ☐☐ Neutral ☐☐ Comfortable ☐☐ Very Comfortable

6. Please select the box that best describes what you learnt today.

A. i. Protons used in proton therapy destroy everything in their way, until the moment they stop.
☐☐ Agree ☐☐ Disagree
ii. Which part of the game stimulated your answer above?
☐☐ Kicking to accelerate the particles ☐ ☐ Selecting the correct energy ☐☐ Selecting the correct direction

B. i. Proton therapy uses accelerator technologies derived from CERN research.
☐ Agree ☐☐Disagree
ii. Which part of the game stimulated your answer above?
☐☐ The graphics on the floor ☐☐☐ The graphics on the wall ☐ ☐ Body movement

C. CERN has no relation with medicine.
☐ ☐ Agree ☐☐ Disagree

7. Please select the box that corresponds to your answer.

	Strongly Disagree	**Disagree**	**Neither Agree or Disagree**	**Agree**	**Strongly Agree**
The presentation of Proton Therapy was clear	☐	☐	☐	☐	☐
By using the game I learned what Proton Therapy is and how it works	☐	☐	☐	☐	☐
I think such games should be used more frequently in learning	☐	☐	☐	☐	☐
While playing I did not feel I was dealing with cancer	☐	☐	☐	☐	☐
While playing I focused more on winning the game than destroying cancer cells	☐	☐	☐	☐	☐
A game about cancer triggers negative emotions	☐	☐	☐	☐	☐
The game helped me feel more at ease about cancer	☐	☐	☐	☐	☐
I believe the game is a light-hearted approach to a sensitive issue	☐	☐	☐	☐	☐
I believe approaching cancer through gaming is more comfortable than talking in person about it	☐	☐	☐	☐	☐

8. How comfortable do you feel talking about cancer **after playing the game**?

☐☐ Less comfortable ☐☐ Same ☐☐ More comfortable

9. How would you rate your overall experience?

☐☐ Poor ☐☐ Fair ☐☐ Average ☐☐ Good ☐☐ Excellent