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The User Experience of an Immersive and Interactive Wall Exergame in Older Adults

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The user experience of an immersive and interactive wall exergame in older adults

Short running title: exergames and older adults

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Abstract

Exergames are promising options for modulating the effects of aging on physical and cognitive functions. A new generation, Interactive and Immersive Wall Exergames (I2WE) has emerged in recent years, offering users freedom of movement, as well as greater and varied interactions with other players, the environment and the system than traditional games (e.g., Wii, Kinect). These features could improve the User eXperience (UX) and thus the engagement and benefits of the intervention for older people. The purpose of this study was to determine whether this kind of exergame could be an effective tool for multi-domain training for the elderly ones. An exploratory study was conducted with 38 healthy older adults who tested a single exergame session to evaluate the UX, the perceived enjoyment as well as the session's workload and intensity. The results show that I2WE generates moderate to high physical intensity, following the recommendations for older people, while the perceived exertion is lower. Moreover, it creates a positive UX correlated with high perceived enjoyment, while producing a suitable session's workload. I2WE appears to be an effective tool to promote physical activity while concurrently stimulating cognition in older adults. The intrinsic characteristics (i.e., immersion, combined physical and cognitive activity, interactions, complex motor skills, playfulness, variety of collective games) give this new type of exergame a promising future. Future studies should be conducted to investigate the effects of a I2WE program on the physical and cognitive functions of older adults.

Introduction

~~Cognitive¹ and energetic² reserve capacities are essential for successful aging, especially in cases of physiological stress (e.g., illness, falls). Aging is accompanied by a normal decrease in physical (e.g., loss of strength and muscle mass, endurance) and cognitive abilities that can be modulated by appropriate training¹.~~ Consequently, there is a need to develop effective enhancement strategies². In recent decades, research has shown that exergames—active video games—produce physical and cognitive benefits in older adults (for review³). However, the research has mainly focused on a first generation of exergames, such as Wii or Kinect. Currently, a new category is developing, called Immersive and Interactive Wall Exergames (I2WE), with systems such as Lumo Play, Play Lü, Iwall and Neo One. Their collective aspect, variety of games, interactions, and their immersive and playful side could offer a motivating factor in multi-domain programs for older people. More specifically, this type of exergame is beneficial because it makes a cognitive task a relevant prerequisite to successfully solving a motor task (e.g., throw the ball at a target at the right time, i.e., Moving while Thinking⁴). These games have an ecological validity, close to the demands of everyday life through the stimulation of general motor skills, which could enhance transfer effects⁴. A recent study⁵ showed the benefits of the Play Lü device on interest and motivation. It also revealed moderate to high intensity generated by adolescents. This intensity is recommended by ACSM's guidelines⁶ to trigger cognitive benefits for the elderly^{7,8}. If it creates a similar intensity, it is possible that I2WE could modulate the effects of physical activity on cognition in older people⁹. However, exergames developed for health and disease prevention purposes should be designed according to the expectations and needs of the target users¹⁰, and I2WE has been the subject of very little research. If not fitted to the elderly, exergames training can lead to cognitive fatigue^{11,12}. It would generate a posture first phenomenon or undue stress, thus less engagement in the activity¹³. These aspects could interfere with the gains of the intervention. In this respect, the session's workload, representing the effort produced by the user to accomplish their task, must be balanced to provide sufficient cognitive stimulation, while ensuring that the physical intensity is sustained enough to generate physical and cognitive benefits. Workload is a relevant tool to evaluate the system¹⁴ and the human performance as well as to design interactive technologies better aligned with the mental capacities of the users¹⁵. To create exergames adapted to the needs and desires of the participants, Nawaz and collaborators¹⁶ advise used a user-centered design approach to involve older adults in the development process right from the start. Meanwhile, Campbell¹⁷ recommends developed an iterative, stepwise approach, where exploratory trials preceded randomized controlled trials in order to measure health effects.

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3 The UX, or the result of the interaction between the user, the system and the context, is a
4 metric increasingly used to assess exergaming for the elderly (e.g.,¹⁸⁻²⁰). The UX shares many common
5 bases with usability²¹, which now appears insufficient to predict and explain the acceptance of
6 technologies. The UX extends usability by adding emotional, subjective and temporal aspects that
7 characterize the individual's experience in contact with technology, which is very important of
8 interactive systems. Beyond the benefits associated with good usability²², a determinant key of high-
9 quality user-system interaction is the creation of products with a good UX²³. Hassenzahl uses a
10 pragmatic-hedonic model of UX²⁴, in which individuals perceive the quality of their interactions with
11 products according to two types of attributes: pragmatic ones, directly related to task accomplishment
12 and product use and the hedonic ones, which emphasize the psychological well-being of individuals.
13 These two attributes combine to generate a global evaluation of product attractiveness. Attractiveness
14 leads to behavioral (e.g., increased usage) and emotional (e.g., pleasure) consequences²⁴. It is useful
15 to evaluate the pleasure experienced while using exergames in relation to the UX, to test the
16 behavioral consequences of Hassenzahl's UX model, especially because of the fun that might
17 encourage players to make movements beyond those strictly required for the game²⁵. In addition,
18 Roto²⁶ suggests including an additional metric of enjoyment to the UX, as other researchers have done
19 (e.g.,^{27,40}).

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21 The purpose of this study was to determine if I2WE are useful tools for multi-domain training.
22 An exploratory trial was set up using a user-centered design approach. Participants tested the new
23 exergame in a single session and filled out a battery of questionnaires. We hypothesized that an I2WE
24 session would create physical intensity in line with the recommendations for older people, with a
25 correct session's workload, and that the UX would be positive and positively related to perceived
26 enjoyment.

27 **Materials and Methods**

28 **Participants**

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30 Thirty-eight participants (29 women) were included in the study (M = 68.26, SD = 5.53), 81.51%
31 of whom had never played exergames previously. On average, they spent 1008.95 METS by week (SD
32 = 683.63), evaluated with QAPPA²⁸ corresponding to a moderate level of physical activity²⁸. They
33 responded positively to a call for participation by email or flyer distributed at associations and clubs in
34 Ile-de-France (France). They met all of the following inclusion criteria: (a) be over 60 years old, (b) be
35 retired, (c) score three or more on a subjective health scale (1 = very poor, 2 = poor, 3 = normal, 4 =
36 good, 5 = very good), (d) have no major pathology, (e) have normal or corrected vision and hearing, (f)
37 have no difficulty bending or using their shoulders, (g) have a certificate of no contraindication to

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3 physical activity.
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6 **Protocol**

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8 The participants were received at a sports center to perform an exergame session, divided in
9 groups of four participants (45 minutes), and then fill in a battery of questionnaires.

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11 For this study, Neo One device was used (Figure 1). It is an I2WE equipped with a video
12 projector and infrared sensors that allow playing with no headphones or equipment. Neo One has a
13 catalog of about 20 games, including sports and puzzle games, that can be played in cooperation or in
14 opposition. For this study, the session was composed of six games (Figure 2). It was preceded by ten
15 minutes of exercises, during which the participants gradually warmed up, while learning to throw and
16 bend to retrieve balls. A sports therapist supervised the session. The instructions and rules of the
17 games were displayed on the screen and re-explained by the supervisor if necessary. The supervisor
18 ensured participants safety by monitoring correct posture.
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26 **Measurement tools**

- 27 • **Heart rate**

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31 During the entire session, the participants' heart rate was measured using a heart rate monitor
32 (Polar Verity Sense). The Theoretical Maximum Heart Rate (TMHR) was first calculated using the
33 formula of Gellish and collaborators²⁹:
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$$36 \text{ TMHR} = 192 - 0.007 \times \text{age}^2$$

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39 Their work²⁹ has reduced the error rate to about 2-5 beats per minute between the ages of 30
40 and 75. This making it the most accurate equation for estimating TMHR to date. The following
41 calculation defines the individual average intensity of the session:
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$$44 \text{ Average intensity} = \frac{\text{Average heart rate} \times 100}{\text{TMHR}}$$

- 45 • **Questionnaires**

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51 **AttrakDiff 2**³⁰ evaluates the UX and was translated and validated in French³¹. Items are distributed
52 among four scales: (a) Pragmatic Qualities (usability and perceived level of ease), (b) Hedonic Quality
53 – Stimulation (supports the need for stimulation with new, interesting and stimulating content,
54 features and interaction styles), (c) Hedonic Quality – Identity (supports a social function and
55 communicates a certain identity of the user), and (d) Overall Attractiveness (overall perceived value of
56 the product based on the perception of its pragmatic and hedonic qualities).
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5 **NASA-TLX**³² evaluates the task's workload. It asks participants to assign a score between 0 and 100 to
6 each of the six dimensions of workload (i.e., mental demands, physical demands, time pressure,
7 performance, effort and frustration). Considering that the NASA-TLX is a multidimensional scale, some
8 dimensions may have a greater weight compared to others in the total score: a weighting procedure
9 can, thus, be implemented to assign a coefficient to each dimension. Because these procedures are
10 contested as being time-consuming³³, researchers³⁴ suggest simply averaging the six dimensions calling
11 it the "**Raw**" **Task Load Index (RTLX)**. These authors showed that the value obtained is highly
12 correlated with the value obtained by the classic calculation procedure. Cegarra and Morgado³⁵
13 verified this property with the French version.
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21 **Physical activity enjoyment scale**³⁶, ten items translated and validated in French³⁷, measures the
22 perceived enjoyment during the practice of physical exercise.
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26 **Modified Borg Scale**³⁸ is a metric of the perceived exertion during exercise. It is scored on a scale of 0
27 to 10, linked to different rating words (e.g., very light, difficult, painful effort).
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31 **Game preferences.** The participants are asked to (a) rank the games in order of preference and (b)
32 state their preferred type of game (i.e., cooperative, competitive, no preference). They are also asked
33 if they would like to repeat the experience.
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38 Results

39 Perceived enjoyment, session's workload and physical intensity

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44 Scores on the *Physical activity enjoyment scale*, the *RTLX*, the *Modified Borg Scale* and the
45 intensity of the session are provided in Table . Perceived enjoyment is high, with a score of 60.71 out
46 of 70. Session's workload, evaluated by the *RTLX*, is correct with a score of 53.46 out of 100. The three
47 dimensions related to the task (i.e., *mental demand*, *physical demand*, *temporal demand*) are balanced
48 and are the highest ones, while *frustration* is the lowest dimension. Mean intensity is 69.64% of the
49 TMHR, which represents the high limit of moderate intensity. Subjective intensity is rated lower with
50 an average of 4.37, corresponding to a perceived exertion as "*easy*" to "*moderate*".
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58 User Experience

- 59 • **Comparison at threshold**
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The area of positivity of the *AttrakDiff2* items is between 1 and 3, that of neutrality between -1 and 1 and the ones of negativity between -1 and -3. Thus, a t-test was performed to compare the averages for the four *AttrakDiff2* items to value 1 (Table 2). Three of the four items are significantly greater than 1 ($p < .05$), thus, considered positive: *hedonic quality stimulation* ($M = 1.68$, $SD = 0.81$), *hedonic quality identification* ($M = 1.32$, $SD = 0.69$), and *total attractiveness* ($M = 2.08$, $SD = 0.79$). Effect sizes are high for *hedonic quality stimulation* ($d = 0.84$) and *total attractiveness* ($d = 1.37$). The *pragmatic quality* score is not significantly higher than 1. It is therefore considered neutral.

- **The character of Neo One**

According to Hassenzhal's model²⁴, four types of product character can emerge by strength of attributes. Depending on the scores obtained on the pragmatic and hedonic dimensions, the evaluated system will be positioned in one of the zones, thus defining its character. Here, Neo One is "desired", with a combination of strong pragmatic and hedonic attributes (Figure 3). The internal goals of accomplishment and achievement, contact and belonging, and task accomplishment are met.

Correlation between measurements

Total attractiveness corresponds to the overall value of the product, based on the perception of pragmatic and hedonic qualities, this score is therefore used for correlational analyses (Table 3). There is a significant positive correlation between *total attractiveness* and *perceived enjoyment* ($r = .50$, $p < .001$), and a negative one with score at *RTLX* ($r = -.34$, $p < .05$) and *modified Borg scale* ($r = -.36$, $p < .05$). Nevertheless, *total attractiveness* and intensity do not appear to be related ($p > .05$).

Game preference and intention to use

Many of the participants expressed no preference regarding the type of game (44.74%), while 36.84% of them said they prefer cooperative games and 18.42% competitive games. *Angry Birds Smash* was the favorite one, followed by *Break It Handball*, *OXO*, *Hit the Beat* and *Oni Goko*. To the question "would you like to repeat this experience", 84.21% answered "yes" and 15.79% "maybe". No participant gave a negative answer.

Discussion

The purpose of this study was to determine whether I2WE could be an effective tool for multi-domain training in older adults. The evaluation protocol was based on metrics of previous studies as well as the specific characteristics of this new exergame.

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3 The first hypothesis was that the session's workload is suitable, with physical intensity in line
4 with the ACSM's recommendations⁶. The average physical intensity was 69.64% of TMRH, which is at
5 the upper limit of moderate intensity (i.e., 55-70% of TMRH), suitable to produce benefits^{7,8}. This
6 intensity is generated through device, which requires participants to use their entire body to succeed
7 in the game (e.g., use their upper body to throw balls, move quickly to hit targets, bend down
8 frequently to retrieve the balls from the ground). This reflects the need to further explore the
9 application of full-body exergames¹⁰, which could generate greater intensity by using the aerobic
10 pathway and muscular resistance through the stimulation of coordination and general motor skills (i.e.,
11 Gross Motor Activities)^{7,39-41}, rather than those that lead only to partial stimulation (e.g., Wii).
12 Moreover, while immersion can increase training intensity⁴², exergames would help to reduce
13 perceived exertion⁴³. The participants rated their perceived exertion at between "easy" and
14 "moderate", lower than the actual intensity. The attractive environment created by immersion⁴⁴
15 and/or by interaction with the system⁴⁵, the playfulness and the collective sessions of this augmented
16 reality exergame can reduce the perceived physical exertion. Indeed, the greater the total
17 attractiveness is, the lower the exertion is perceived. Additionally, the session's workload was suitable,
18 which is necessary to stimulate cognitive functions while avoiding potential negative effects. To be
19 more precise, *physical, mental and temporal demands* were balanced. This means that the participants
20 were able to distribute their resources equally and that there was no prioritization of task, as can be
21 the case in dual tasks. Moreover, the session did not generate frustration and the low score on the
22 *performance* dimension showed that the participants succeeded in reaching their goal, with the
23 immersive aspect allowing better performance⁴⁶. Again, the total attractiveness and session's
24 workload were negatively related, reflecting the potential for immersion and interaction to modulate
25 the impression of stimulation. Nevertheless, although *NASA-TLX* is the gold standard for assessing
26 workload in the field of Human-Computer Interaction¹⁴, there is no standard for determining whether
27 the workload is too high. Thus, I2WE generates and conceals moderate-to-intense physical intensity in
28 line with the recommendations, while producing a correct session's workload.

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47 The second hypothesis was that the UX is positive and positively related to perceived
48 enjoyment. According to other studies evaluating conventional exergames UX (e.g.,⁴⁷⁻⁴⁹), this new kind
49 generated a good UX for the elderly participants. Based on Hassenzhal's model²⁴, it is "desired". The
50 internal goals of accomplishment, achievement, contact, belonging, and task accomplishment goals
51 were met. While 81.51% of the participants had never played exergames previously, 84.21% answered
52 that they would like to repeat the experience. This reflects the accessibility of the I2WE, which was not
53 designed specifically for the elderly, and the possibilities of use by them. However, the *pragmatic*
54 *quality* item, relating to the instrumental aspects of the system, is not considered positive. Although
55 the product fulfills its purpose without having a negative impact⁵⁰, the UX could still be improved by
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3 increasing *pragmatic quality*. Its evaluation represents users' perceived ability that interactive
4 products allow them to manipulate the environment to accomplish their objectives. Since some
5 aspects of the game, particularly its speed⁵¹, may have had a negative impact, designers should
6 consider the functional, cognitive, and sensory limitations related to aging⁵². This is reflected in the
7 participants' game preferences: the two games (i.e., *Angry Birds Smash*, *Break It Handball*) with simple
8 gameplay and fewer instructions, easier to be understand. Therefore, the clarity, structure and
9 predictability of I2WE games must be designed carefully to be suitable for older people. Despite this
10 drawback, the present study confirms their potential in creating pleasure in the elderly^{20,27,53,54}, which
11 could be one of the only factors constituting motivation to practice physical activity after the age of 70
12 years⁵⁵. This is even more positive since the participants had no previous experience with exergames
13 and might therefore have been refractory. Physical activity paired with technology usually provides
14 more enjoyment than traditional interventions⁵⁶ and should therefore be used as a motivating factor.
15 The collective aspect and the presence of a partner could also be factors of pleasure⁵⁷. According to
16 Hassenzhal's model²⁴, the UX will lead to behavioral (e.g., increased usage) and emotional (e.g.,
17 enjoyment) consequences that will determine whether the product is appealing or not. In the present
18 study, perceived enjoyment and the UX were both high and positively related, with a high effect size.

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30 The main limitation of this study concerns the characteristics of the participants. On the one
31 hand, the study sample is not purely representative of the senior population. It includes more women
32 (n = 28) than men (n = 10). On the other hand, the subjects participated voluntarily in the study, which
33 may affect the results, especially as the aim was to assess their feelings (i.e., enjoyment, UX) about the
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There is discordance in the literature regarding the choice of methodology to be used to
determine whether an exergame is suitable for older adults. Studies generally choose between one
and three modalities (e.g., acceptability, effectiveness, usability, engagement) depending on the type
of study but also on the characteristics of the exergame¹⁶. In the future, a replicable protocol for
evaluating the use of exergames with older adults needs to be developed. Usability is still overused
despite it does not seem to be a sufficiently relevant tool. These products need to be evaluated using
other metrics, such as UX, to consider more subjective aspects that are omnipresent in the experience,
especially with these new exergames. This exploratory trial showed that I2WE are favorable tools for
multi-domain training for the elderly. Still, it would have been interesting to compare this tool with
other more classic devices such as Wii or Kinect, which have already shown their benefits. In addition,
qualitative data complementing the quantitative data^{16,58} to provide a better understanding of older
adults' experiences with exergames. This new type of exergames could be applied to rehabilitation and
reeducation environment (e.g., SSR, hospitals) as well as care facilities (e.g., EHPAD, residences) for
older people. However, only future larger studies with a randomized controlled trial, as Campbell¹⁷

advises, to measure the effects of a program with an I2WE on the physical and cognitive functions will be able to demonstrate the clinical benefits.

Conclusion

Although they are not specifically designed for older adults, I2WE generate a positive UX and high perceived enjoyment. Physical stimulation is of moderate intensity, which solicits the aerobic pathway and muscular resistance, using general motor skills. Simultaneous cognitive stimulation is integrated with the physical task, resulting in a correct session's workload. Moreover, collective practice, great freedom of movement, and the variety of games and interactions constitute their richness. Since cognitive training sometimes lacks ecological validity, and physical training lacks playfulness, this new type of I2WE seems to have a promising future.

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Authors contributions statement

Author 1: conceptualization (equal); formal analysis (lead); investigation; methodology (equal), writing – original draft (equal); writing – review & editing (equal). **Authors 2 and 3:** conceptualization (equal); formal analysis (supporting); methodology (equal); project administration (lead); supervision (lead); writing – original draft (equal); writing – review & editing (equal); writing – original draft (equal), writing – review & editing (equal).

Conflict of Interest

The authors declare that they have no conflicts of interest.

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Tables

Table 1. Scores of perceived enjoyment, mental load and physical intensity

	Mean	SD
Perceived Enjoyment (score)	60.71	6.04
RTLX (score)	53.46	14.28
<i>Mental demand (score)</i>	63.16	25.80
<i>Physical demand (score)</i>	62.37	26.65
<i>Temporal demand (score)</i>	64.47	23.79
<i>Effort (score)</i>	57.63	22.50
<i>Performance (score)</i>	39.74	16.52
<i>Frustration (score)</i>	33.42	23.11
Modified Borg Scale (score)	4.37	1.55
Mean Intensity (percent of TMHR)^a	69.64	9.11

Table 2. Difference scores to standard 1

	Mean	SD	df	t	p	d
Pragmatic quality	0.91	0.89	1	0.65	.52	-0.10
Hedonic quality stimulation	1.68	0.81	1	5.18	<.001	0.84
Hedonic quality identification	1.32	0.69	1	2.90	<.01	0.47
Total attractiveness	2.08	0.79	1	8.44	<.001	1.37

Table 3. Correlations between total attractiveness, perceived enjoyment, workload and intensity

Variables		Total attractiveness	Perceived enjoyment	Workload	Modified Borg
Total attractiveness (score)	Pearson's r	-			
	p-value	-			
Perceived enjoyment (score)	Pearson's r	0.50	-		
	p-value	<.001	-		
Workload (score)	Pearson's r	-0.34	0.12	-	
	p-value	<.05	0.46	-	
Modified Borg (score)	Pearson's r	-0.36	0.06	0.51	-
	p-value	<.05	0.73	<.001	-
Mean intensity (percent of TMHR ^a)	Pearson's r	0.10	0.18	0.17	-0.21
	p-value	0.56	0.29	0.30	0.21

Figure Legends

Legend Figure 1. *As Hit the Beat is played by two players, the other two participants perform a muscle-strengthening exercise: sit-stand on a chair while throwing a ball. In pairs, facing each other, the subjects must stand up, make a pass and sit down again in a coordinated manner. The objective is to make as many passes as possible in 30 seconds. The exercise is performed twice.

Legend Figure 2.

● AttrakDiff 2 score

■ Confidence interval

ACT: product with strong pragmatic qualities and weak hedonic qualities.

SELF: product with weak pragmatic qualities and strong hedonic qualities.

^aTMHR: Theoretical Maximal Heart Rate

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Figure 1. Neo One device

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Terms and conditions:	
5 minutes, foam ball in hand, easy difficulty	
<p>Oni Gokko. Participants must complete several challenges in the form of mini-games: Hangman, Hunt and Seek, Memory and Mixed Letters games. The objective is to win as many points as possible.</p> <p>Angry Birds Smash. This game consists of destroying as many fortresses and pigs as possible on the screen to pass the levels. The objective is to succeed in the different levels and reach the highest score in the time limit.</p> <p>Break It Handball. This game consists of aiming at the various bricks that appear on the screen to pass the levels. The objective of the game is to succeed the different levels and reach the highest score in the time limit.</p>	<p>4 to 0</p> <p>Cooperative</p>
<p>OXO. This game is based on the mechanics of tic-tac-toe. The objective is to align 3 symbols on the grid to win and prevent one's opponents from doing the same.</p> <p>Ice Cream Factory. Two teams compete to complete ice cream orders as quickly as possible and win coins. The team with the most coins at the end of the time wins.</p>	<p>2 to 2</p> <p>Competitive</p>
<p>Hit the beat.* In this game, participants must hit targets that appear at the right time to the rhythm of the music.</p>	<p>1 to 1</p>

Figure 2. Description of games used

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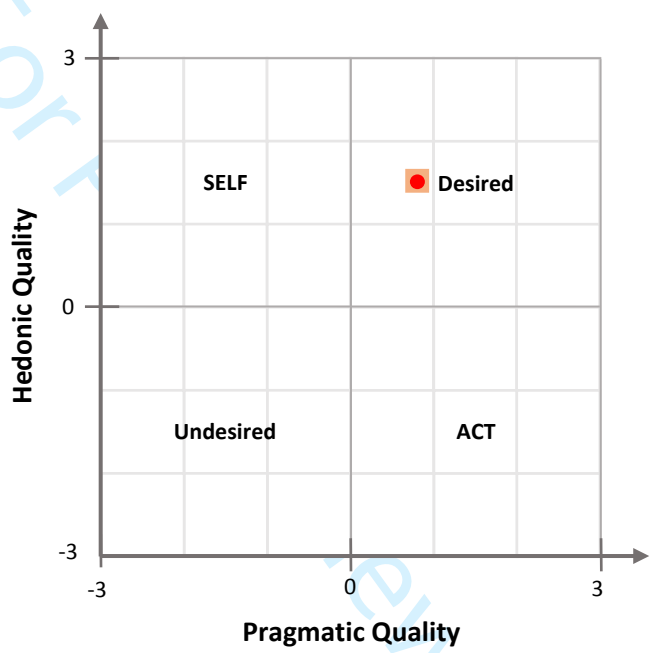


Figure 3. Neo One character, emerging from specific combinations of pragmatic and hedonic attributes. Translated from Hassenzhal's model²⁵

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