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Original Article

Brain Training for Silver Gamers: Effects of Age and Game Form on Effectiveness, Efficiency, Self-Assessment, and Gameplay Experience

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Abstract

In recent years, an aging demographic majority in the Western world has come to the attention of the game industry. The recently released "brain-training" games target this population, and research investigating gameplay experience of the elderly using this game form is lacking. This study employs a 2×2 mixed factorial design (age group: young and old×game form: paper and Nintendo DS) to investigate effects of age and game form on usability, self-assessment, and gameplay experience in a supervised field study. Effectiveness was evaluated in task completion time, efficiency as error rate, together with self-assessment measures (arousal, pleasure, dominance) and game experience (challenge, flow, competence, tension, positive and negative affect). Results indicate players, regardless of age, are more effective and efficient using pen-and-paper than using a Nintendo DS console. However, the game is more arousing and induces a heightened sense of flow in digital form for gamers of all ages. Logic problem–solving challenges within digital games may be associated with positive feelings for the elderly but with negative feelings for the young. Thus, digital logic-training games may provide positive gameplay experience for an aging Western civilization.

Introduction

Are new, ubiquitous technologies and media forms, like digital games on portable consoles, a blessing or a curse for an aging Western civilization? Recently, educational games (e.g., brain-training games) are inflating the portable console market. They are branded as successful drivers of mental health for the elderly, and researchers suggest that they can increase math skills of schoolchildren.[1] However, aside from the discussion of long-term mental benefits, it is imperative to first ask whether solving logic problems on paper or within digital games makes any experiential difference at all, especially for an elderly population. This study presents an initial investigation of this first pertinent question: Do game form and age have any influence on gameplay experience and related concepts, such as arousal[2] and usability?[3]

Since the Western world's aging population is growing, an older demographic becomes more interesting as players of digital games. Whitcomb[4] reviewed pre-1990 studies investigating how games affect the elderly. The review shows that "only a limited number of computer games are enjoyable for the elderly," but there is a positive effect of games for this age group on perceptual-motor skills,[5] reaction times,[6,7] cognitive skills and attitude toward technology,[8] and interest in learning.[9] These studies investigate effects of long-term exposure of digital games on elderly people. However, no direct investigation or online measure of gameplay experience is prominent. More recent investigations of gaming for an elderly demographic have focused on detailed game and interface design considerations,[10] brain-fitness applications,[11] and the association of subjective well-being and improvement in reaction time as part of long-term game playing,[12] but effects of game form on gameplay experience have not been studied before for this age group.

One study on the effects of media form on usability factors compared effectiveness, efficiency, and satisfaction for students solving a quiz task using a personal digital assistant (PDA) or paper and pencil.[3] Efficiency was measured as time-to-completion, effectiveness by student quiz scores and a mental workload questionnaire, and satisfaction with a questionnaire. Students were faster (i.e., more efficient) in solving the quiz with the PDA, but no form effects on effectiveness and satisfaction were found. Another study compared an electronic PDA-based barcode entry system to a pen-based input system for participants over age 60 years.[13] The barcode system scored higher in usability and pleasantness—the pen entry worked faster. Finally, a study with undergraduate participants investigated effects of medium (movies vs. games) and form (portable and television-based) on physiological arousal and flow.[2] Consistent for

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games and movies, results showed portable media consoles evoke lower levels of physiological arousal and flow experience than do television-based consoles. The flow experience concept was first introduced by Csikszentmihalyi, consisting of clear goals, immediate feedback, balance of challenge and personal ability, loss of self-consciousness, blurred feeling of time, and feeling of enjoyment and control in an intrinsically rewarding activity.[14]

Most studies of medium or form effects focus on usability evaluations for input devices regarding college students.[15] Thus, there is a need to investigate how different age groups experience games using different gaming forms. Is gameplay experience for young players different from elderly players in a digital game? How does this differ when the game is played on paper? Using a basic problem-solving game mechanic on paper and on a Nintendo DS console, we investigate whether differences in gameplay experience and usability factors relate to game form or age.

Effects of game form or age on usability factors: efficiency and effectiveness

Merzenich[11] noted that a good user experience is related to good usability, especially for the elderly. This is in line with theoretical models suggesting usability to be a fundamental contributing factor of gameplay experience.[16] Usability is standardized by the International Organization for Standardization (ISO)[17] to consist of three major aspects: effectiveness, efficiency, and user satisfaction. Sauro[18] suggested measuring effectiveness in completion rates and errors, efficiency in time spent on task, and satisfaction with a questionnaire. Prior studies suggest that game form will positively influence efficiency.[3] Since young people are likely to be more familiar with portable game devices, they are more likely than older people to resolve a game task efficiently on a game console. Conversely, since older people have been socialized with pen-and-paper techniques, they should be more efficient using this game form. This is in line with the literature, since studies suggest the elderly are faster using pen and paper than using a portable PDA-like device.[3,13] We extend this assumption to account for effectiveness in addition to efficiency:

H1: Game form and player age exercise an interaction effect on task *efficiency*, since younger individuals will finish the game task faster on a Nintendo DS console than on paper, whereas elderly individuals will finish the game task faster on paper than on the game console.

H2: Game form and player age exercise an interaction effect on task *effectiveness*, since younger individuals will finish the game task with fewer errors on a Nintendo DS console than on paper, whereas elderly individuals will finish the game task with fewer errors on paper than on the game console.

General effects of game form and player age on experience

For evaluating an enjoyable game experience, simple user satisfaction measures will not suffice. Since games have a stronger focus on entertainment and a pleasurable experience, player satisfaction should be measured more distinctively than user satisfaction. A study with an elderly player group observed alterations in the factors arousal, pleasure, and dominance for elders who played video games regularly for an 8-week period.[19] Here, gaming increased the arousal scores, whereas pleasure scores declined, which was likely associated with frustration in learning to play. Dominance scores were not affected and remained at high levels. Thus, the three examined emotional dimensions (pleasure, arousal, dominance) seem to be suitable for evaluating game experience. As mentioned previously, a study of a younger age group found that decreased technological sophistication evokes lower levels of arousal and flow.[2] Thus, we argue that playing the game in the pen-and-paper condition will likely evoke less arousal and flow than on a DS.

H3: Game form will have a main effect on arousal and flow, because regardless of age, playing on paper will elicit less arousal and less flow than playing on the Nintendo DS console.

IJsselsteijn et al.[20] theorized that *immersion*, *tension*, *competence*, *flow*, *negative affect*, *positive affect*, and *challenge* are important elements of gameplay experience. The concept of flow[14] is linked directly to challenge, because engaging in challenges fitting to an individual's capacity is a precursor for flow experience to occur.[21] Thus, we argue that if flow is likely to be higher on the game console, then challenge will be higher on the game console as well. Moreover, flow and challenge will likely be related to a positive game experience (indicating a correlation with positive affect).

H4: Game form will have a main effect on positive game-related challenge, because challenge will be higher on the Nintendo DS console than on paper, and flow will correlate with challenge and positive affect.

Method

Design

We employed a 2×2 mixed factorial design (using age group as between-participants and game form as within-participants independent variables), which was carried out as a supervised field study using a counterbalanced, randomized order of stimuli exposure and a limited number of psychological questionnaires in order to keep the workload low for the elderly participants. Our main interest was in analyzing a senior demographic aged 65 and older, which is currently not well served by most commercial games on the market.[10] To ascertain genuine effects of age, we also tested the stimuli with a younger group (between 18 and 25 years old).

Participants

We collaborated with a physiotherapist to recruit elderly participants. Twenty-one German individuals between 65 and 90 years old were chosen for this group. All participants were screened for mental and physical well-being. Subsequently, the physiotherapist invited them to the study. In this elderly group (33.3% male, 66.7% female), with a mean age 74.52 years ($SD = 8.93$), only 9.5% were institutionalized; the rest lived independently. Of the group, 47.6% were married; 76.2% reported full hearing, while the remaining reported using a hearing aid; 23.8% stated they had used a computer and 14.3% that they had played a digital computer game before. All individuals were familiar with physical board and card games and played several of them. Nineteen students (52.6% male, 47.4% female) between 18 and 25 years old

($M = 21.47$, $SD = 2.47$) were chosen for the younger comparison group. All of them had previously used a computer and played digital games as well as card and board games.

Stimulus materials

We used the popular Nintendo DS game Dr. Kawashima's Brain Training (Nintendo, 2006) and one of its arithmetic challenges, the 20 equations calculation game, as a test stimulus. The game requires the player to calculate 20 different random equations, using the mathematical operations of addition, subtraction, and multiplication, in the shortest time possible. The time taken for solving these 20 equations is used to give reward points for playing the game and to generate a high score among players. In order to compare the repeated-measures effect of form, each participant played the game in two modalities: on a piece of paper and using a Nintendo DS console. Since this study was exploratory, an investigation of the simplest game mechanics possible was chosen in order to strengthen internal validity of the experiment and to pave the way for future studies with more complex game mechanics. From observations during the experiment, all participants in both age groups considered this "simple" playful task as an entertaining and challenging game.

Measures

Three groups of dependent variables were observed for each participant in the different age groups in each playing condition according to our hypotheses: usability variables were *error rate* and *time-to-completion*; self-assessment variables were *pleasure*, *arousal*, and *dominance*; and subjective player experience variables were *flow*, *competence*, *challenge*, *positive affect*, *negative affect*, and *tension*.

- The experimenter measured time-to-completion in seconds with a standard digital stopwatch. Error rate was measured as the number of errors made on the Nintendo DS console and on paper. The Nintendo DS automatically reports error rates; for errors on paper, the experimenters checked the correctness, and a math teacher double-checked the results. To check whether error rate was related to perceived input recognition on the game console, a 5-point-scale questionnaire control item from 1, *extremely disagree*, to 5, *extremely agree*, was included ("The device did not correctly recognize my handwriting").
- Pleasure, arousal, and dominance were evaluated using the self-assessment mannequin (SAM)[22] on a modified 9-point scale, showing five mannequins with four separator items between them. For example, the SAM pleasure scale depicts five graphic figures ranging from a happy, smiling character (9) to an unhappy, frowning character (1).
- The game experience questionnaire[20] (GEQ) combines several game-related experiential measures. The questionnaire is based on focus group research[23] and subsequent survey investigations among frequent players. Flow and challenge were examined with five questionnaire items for each dimension; and competence, tension, negative affect, and positive affect were examined with two questionnaire items for each dimension. The sensory and imaginative immersion dimension was dropped because questions were not considered suitable for investigating the arithmetic game mechanic in this study. Each item consists of a statement on a 5-point scale ranging from 0, *disagree*, to 4, *completely agree*. Two extra items checked whether auditory clues ("The auditory feedback was motivating for me") and/or visual clues ("The visual feedback was motivating for me") on the game console were motivators for a different game experience.

Procedure

All experiments were conducted at home or in institutions where individuals lived (in the German cities of Köln, Essen, and Bremerhaven). If a trial was conducted in an institution, permission was first obtained from the local authorities. To ensure highest ecological validity and create a comfortable atmosphere, all individuals were located in a comfortable position with proper lighting conditions to fulfill the experimental tasks. Participants were informed about the goals and procedure of this study. An informed consent form was handed out (with general information and a warning to not take part in the experiments if suffering from gambling addiction or epileptic seizures), which was mandatory to sign to proceed with the study. The experimenter briefly interviewed participants about their living situation and then gave them the prestudy demographic questionnaire. In a randomized, counterbalanced order, individuals were informed about the required tasks. The experimenter measured the time for each task. After each of the tasks, individuals filled out the postgame evaluation questionnaires. Although the paper game was an exact reproduction of the Nintendo DS game, the experimental procedure was slightly different.

For the paper game task, the participants were allowed to calculate three nonstimulus equations first to test their correct understanding of the procedure. The experimenter answered any questions at this point and presented a piece of paper with 20 mathematical equations. All equations except for the first one were covered with another piece of paper. The participants were instructed to calculate only one equation at a time, in sequential order, and were supervised not to go back and correct a solution that they deemed to be wrong (this procedure emulates the exact procedure from the Dr. Kawashima's Brain Training Nintendo DS game). During the calculation game, no discussion or questions were allowed. After participants completed the paper game task, the experimenter recorded time-to-completion and collected the calculation papers, which were put into a bag to be assessed later without the participants present.

For the Nintendo DS game task, using the digital game Dr. Kawashima's Brain Training, a short explanation of the Nintendo DS device and its touch screen was given to the elderly participant group (all participants in the younger group knew how to use a Nintendo DS). Each elderly participant then underwent training in using the console device by writing their name in letters and writing several numbers on the touch screen for 5 minutes. The experimenter then briefly explained how to play Dr. Kawashima's Brain Training, and the participants were asked to calculate three nonstimulus equations using the touch screen. Any remaining questions had to be asked at this point. After participants completed the Nintendo DS game task, the experimenter recorded time-to-completion and error rate (calculated by the game) to be assessed later without the participants present.

Results

Usability measures

The usability literature points to time-to-completion as a measure of efficiency and error rate as a measure of effectiveness.[18] Our study examines whether a game task can be solved more efficiently on paper or on the Nintendo DS console. Prior research suggests that young people take less time on the game console and elderly people take less time on paper (H1); we also examine whether this hypothesis holds for effectiveness (H2). The time it took individuals to complete the game task was measured in seconds. Figure 1(A) reveals that solving the game task takes longer on the Nintendo DS console than on paper, regardless of age, but also that elderly people take longer in general to solve the task than do young people, regardless of game form. To test the significance of this finding, a two-way mixed analysis of variance (ANOVA) with age as a between-participants factor and game form as a within-participants factor was conducted for both dependent variables: time-to-completion (H1) and error rate (H2). Multivariate analysis revealed a significant general between-participants effect of age group, $F(2, 37) = 22.17$, $p < 0.001$, $\eta_p^2 = 0.55$, and a significant general within-participants effect of form, $F(2, 37) = 5.51$, $p < 0.05$, $\eta_p^2 = 0.20$.

Univariate tests showed a significant main effect of form on time-to-completion, $F(1, 38) = 4.52$, $p < 0.05$, $\eta_p^2 = 0.11$. Solving on the game console takes longer than on paper, regardless of age. Between participants, a significant main effect of age on time-to-completion, $F(1, 38) = 38.93$, $p < 0.001$, ${\eta_p}^2 = 0.51$ was discovered, meaning that older people take longer than younger people, regardless of game form. No significant interaction effects between age and game form were found, however.

Although we expected our younger age group to be efficient with modern technology, H1, that game form and player age exercise an interaction effect on task efficiency, is not supported: solving the task takes longer on a game console than on paper, regardless of age. This means, however, that we can support our assumption that elderly people take less time to solve on paper than on the game console, and we

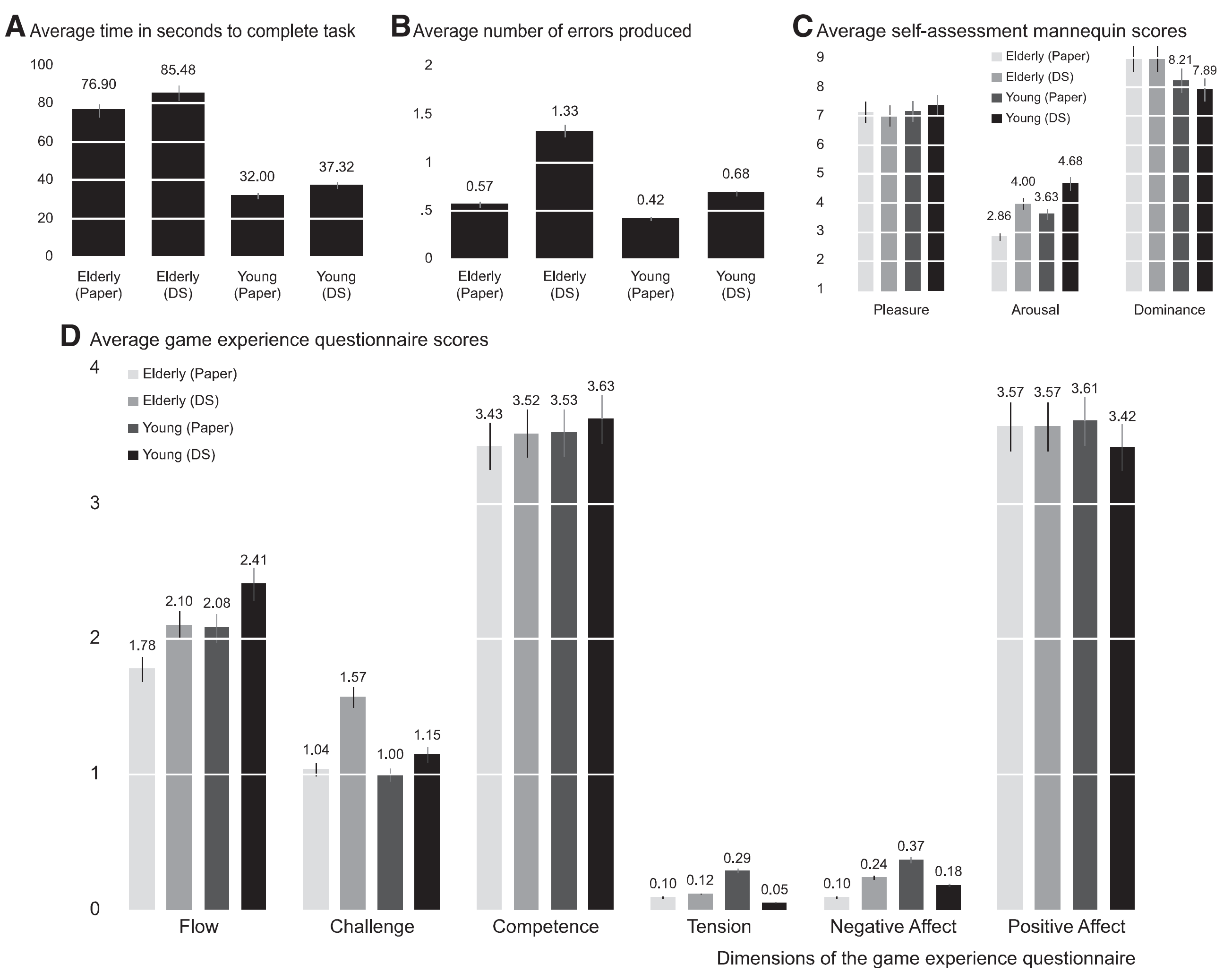

FIG. 1. Results of the dependent variables as bar charts with error bars showing 95% confidence interval of mean. (**A**) Efficiency as average time to complete the task. (**B**) Effectiveness as average number of errors produced. (**C**) Average SAM scores of pleasure, dominance, and arousal. (**D**) Average GEQ scores of flow, challenge, competence, tension, negative affect, and positive affect.

note that elderly people in general take more time than young people to complete the task. This might be because elderly people are more familiar with pen and paper than with modern gaming technology or because of the complex cognitive requirements of this technology. Given that another study using a PDA-based quiz found no effectiveness differences between the pen-and-paper and PDA conditions,[3] we checked the correlation of error rate and time-to-completion, $r = 0.51$, $p < 0.001$, which suggested an effectiveness difference between pen and paper and the Nintendo DS console.

For H2, that game form and player age exercise an interaction effect on task effectiveness, we investigated whether we could find the same pattern for the results of error rate. A similar pattern emerged for the average number of errors made, as shown in Figure 1(B). Individuals of both age groups produced fewer errors when playing the game on paper than on the Nintendo DS console. While the multivariate analysis reported above suggests that significant differences could be found for both age and form, univariate tests showed significant effects only of form on error rate, $F(1, 38) = 7.18$, $p < 0.05$, $\eta_p^2 = 0.16$, but no effect of age on error rate. This result is not surprising in light of our findings on efficiency, but it contradicts the literature[3] and does not support H2.

The most reasonable explanation for this result would be problems with the text recognition on the Nintendo DS console. The correlation of the input-recognition questionnaire control item with time-to-completion ($r = 0.46$, $p < 0.01$) and error rate ($r = 0.52$, $p < 0.01$) supports this explanation. An alternative explanation could be that younger individuals may be faster, given their motor skills, but similarly effective in their cognitive ability to solve the game tasks. Finally, confounding effects of gender were checked in another mixed ANOVA with gender as additional between-participants factor but showed no significant main or interaction effects for time-to-completion or error rate.

Self-assessment (SAM)

In line with prior studies on form effects on physiological arousal,[2] we hoped to discover effects of age or form on subjective pleasure, arousal, and dominance as measured with the SAM scale.[22] Individuals in both age groups indicated an equally pleasurable experience (~ 7 on the 9-point scale, indicating high pleasure) for both game types, shown in Figure 1(C). Significance was tested for pleasure, arousal, and dominance with a two-way mixed ANOVA with age as a between-participants factor and form as a within-participants factor. While multivariate tests revealed a significant between-participants effects for age, $F(3, 36) = 6.69$, $p < 0.01$, $\eta_p^2 = 0.36$, and significant within-participants effects for form, $F(3, 36) = 5.08$, $p < 0.01$, $\eta_p^2 = 0.30$, the univariate tests showed no significant main or interaction effects on pleasure. Thus, it must be assumed neither age nor form affected the perceived pleasure when playing.

H3 also states that playing on paper will elicit less arousal than playing on the Nintendo DS. Figure 1(C) shows that H3 is supported. Nevertheless, SAM arousal ratings were generally below the mid-range (5) of the 9-point scale (indicating generally low arousal for the game task). This could be due to the nature of the arithmetic game, which might be less arousing than more complex game mechanics. The univariate results of the mixed ANOVA support this finding, which showed a main effect of form on arousal, $F(1, 38) = 15.29$, $p < 0.001$, $\eta_p^2 = 0.29$, but no main effect of age or significant interaction effects between age and arousal. Thus, the part of hypothesis H3 that arousal is higher for playing on the game console than on paper is supported regardless of age. The SAM dominance scale results show a difference between age groups in Figure 1(C). While elderly people felt equally dominant (which is supported by long-term studies)[19] regardless of form, the younger age group felt less dominant, especially when playing with the Nintendo DS. The univariate results of the mixed ANOVA accordingly showed a significant between-participants effect of age on dominance, $F(1, 38) = 18.71$, $p < 0.001$, $\eta_p^2 = 0.33$.

This finding supports the literature[19] and raises questions for future research, since the feeling of control over a game seems unaffected by game form, which suggests that this experiential dimension could possibly be constant for elderly regardless of the independent variables employed in a study. That the elderly made more errors and took more time for the game task than the young group did does not seem to have affected their subjective self-impression of dominance. Another mixed ANOVA ruled out effects of gender, showing no significant main effects or interactions.

Gameplay experience

The final part of this investigation was the analysis of player age and game form effects on six gameplay experience dimensions of the GEQ: flow, challenge, competence, tension, negative affect and positive affect. A brief check of the reliability of each GEQ dimension revealed that flow (Cronbach's $\alpha = 0.9$), positive affect (Cronbach's $\alpha = 0.8$), and challenge (Cronbach's $\alpha = 0.7$) were the only dimensions with an acceptable reliability for both paper and Nintendo DS. For paper, tension was also barely acceptable (Cronbach's $\alpha = 0.7$), while competence and negative affect were unreliable (Cronbach's $\alpha < 0.5$). For Nintendo DS, competence, negative affect, and challenge were all reliable (Cronbach's $\alpha \geq 0.8$), while tension was not (Cronbach's $\alpha < 0.5$). We expected that flow would be weaker on paper than on the Nintendo DS console (H3). Figure 1(D) shows this was true for average scores not only in the flow dimension but also in the challenge and competence dimensions. However, for the young group, the opposite is true: scores in tension, negative affect, and positive affect were lower in the Nintendo DS condition. Both age groups scored high (between 3 and maximum 4) for competence and positive affect, indicating that playing the game on paper and on the Nintendo DS kept them in a comfortable zone.

More interesting is the increase flow and challenge from paper to Nintendo DS, which indicates an effect of form on flow and possibly on challenge in line with our hypotheses (H3 and H4). This finding was checked for significance with a two-way mixed ANOVA with age as a between-participants factor and form as a within-participants factor for the GEQ dimensions. Multivariate results showed a significant within-participants main effect of form, $F(6, 33) = 3.02$, $p < 0.05$, $\eta_p^2 = 0.35$, as well as a significant interaction effect of form and age, $F(6, 33) = 2.78$, $p < 0.05$, $\eta_p^2 = 0.34$. The latter suggests that the type of form used has a different effect depending on the age of the participants. However, the subsequent univariate analysis showed no significant interaction effects of age and form on any of the game experience dimensions. Nevertheless, significant main effects of form on flow, $F(1, 38) = 7.24$, $p < 0.05$, ${\eta_p}^2 = 0.16$, and on challenge, $F(1, 38) = 9.24$, $p < 0.01$, ${\eta_p}^2 = 0.20$ were found. Thus, regardless of age, playing on the Nintendo DS console induced more challenge and more flow. These findings, along with the those on the SAM arousal dimension, support H3, that playing on the Nintendo DS elicits more flow and more arousal than does playing on paper, regardless of age.

H4, that while challenge scores will be higher on Nintendo DS than on paper, flow will also correlate with challenge as well as positive affect, is also supported. For all participants, regardless of age or game form, flow correlates with challenge, $r = 0.57$, $p < 0.001$, and with positive affect, $r = 0.41$, $p < 0.001$, as well as with pleasure, $r = 0.49$, $p < 0.001$, arousal, $r = 0.34$, $p < 0.01$, and competence, $r = 0.48$, $p < 0.001$. When correlations are split between age groups, flow for the elderly group correlates with the same dimensions except arousal, but another correlation with tension, $r = 0.32$, $p < 0.05$, occurs. However, for the young group, flow correlates only with challenge, $r = 0.43$, $p < 0.01$, and arousal, $r = 0.42$, $p < 0.01$. So part of H4, that flow will correlate with positive affect, is rejected for younger individuals.

These results suggest that different game elements may facilitate flow for different age groups. Younger individuals might find it easier to find flow through an exciting and challenging task, which does not necessarily have to be connected to a positive emotion, while elderly people might prefer something that elicits positive emotion and is related to tense feelings rather than feelings of excitement. When checking for confounding effects of gender, another mixed ANOVA showed a significant within-participants interaction effect of form by gender by group, $F(6, 31) = 2.53$, $p < 0.05$, ${\eta_p}^2 = 0.33$. The following univariate analyses showed significant interaction effects of form and gender on negative affect, $F(1, 36) = 7.93$, $p < 0.01$, ${\eta_p}^2 = 0.18$, and tension, $F(1, 36) = 4.71$, $p < 0.05$, ${\eta_p}^2 = 0.12$, which is not discussed in detail because of the lacking reliability of these GEQ dimensions.

In addition, significant interaction effects of form and age on challenge, $F(1, 36) = 5.11$, $p < 0.05$, $\eta_p^2 = 0.12$, and on negative affect, $F(1, 36) = 6.75$, $p < 0.05$, $\eta_p^2 = 0.16$, were found. Again, we skip a discussion of negative affect because of its unreliability. Instead, the observed interaction effect of form and age on challenge may explain the general interaction effect of form and age found in the previous ANOVA (which did not account for gender as a moderator). Figure 1(D) may explain this result, since we can see a higher challenge score for the elderly group on the Nintendo DS, whereas the increase in challenge is not as prominent for the young group. However, challenge is an ambiguous item and can denote either a positive or a negative gameplay experience. Therefore, correlations were tested, and in addition to a positive correlation between challenge and flow for both elderly and young, for the elderly group, a correlation between challenge and *positive* affect, $r = 0.41$, $p < 0.01$, was found. In contrast, for the young group, a correlation between challenge and *negative* affect, $r = 0.35$, $p < 0.05$, was found. Thus, elderly individuals might like challenge more than young individuals do, suggesting that during the experiment, the elderly participants experienced challenge as positive for their gameplay experience, while the young participants experienced challenge as negative for their gameplay experience.

Discussion

We found that for both the young and elderly groups, time spent for solving the game task increased from paper to the game console. Thus, H1 was not supported: solving the task takes longer on the Nintendo DS than on paper regardless of age. But the assumption that elderly people take less time on paper to solve the game task was supported. In general, we observed that elderly people take longer than young people for the game task. The same pattern was detected when investigating the number of errors produced during the task, not lending support to H2. However, after correlation with a control item, the most reasonable explanation for this result seems that there were problems with the text recognition on the DS. This raises the question of whether the audiovisual elements of the console distract from the basic tasks, thus providing more challenge. Although challenge did not correlate directly with those elements, this suggestion might be supported partially for the younger age group by the correlation of flow and challenge and the correlation of visual and auditory clues as motivators for flow. Thus, the more motivating the young individuals found the audiovisual elements, the more likely they were to experience flow. However, such a scenario is unlikely to hold for the elderly age group, as audiovisual cues were found to improve a more pleasurable experience, and visual cues were found to enhance their feeling of competence. It would then also be necessary to revisit Merzenich's[11] advice on usability for the elderly. Since Dr. Kawashima's Brain Training on the Nintendo DS was designed with an elderly audience in mind, it should improve usability factors, but from our findings, it improves positive feelings in the elderly only when solving an arithmetic task, but it does not improve usability factors like effectiveness and efficiency. Nevertheless, future research could more thoroughly investigate the relationships among motor and cognitive skills, prior experience with portable game devices, and their influence on the efficiency and effectiveness of game consoles.

H3 was supported. We can confirm prior findings that decreased technological sophistication evokes lower levels of arousal and flow[2] and that this is true regardless of individual age. In line with prior research[19] was the finding of unchanged dominance for elderly people, which raises the question why the feeling of control over a game seems unaffected by game form.

While we initially proposed that flow[14] is linked directly to challenge, the preferred type of challenge seems to differ between young and old. H4 stated that game form will have a main effect on positive game-related challenge, since challenge will be higher on the Nintendo DS than on paper, and flow will correlate with challenge and positive affect, this was only partially supported. A correlation analysis showed that arousal might be an important facilitator for flow for the younger age group, while for the older age group, pleasure, competence, and positive affect are all contributors to their flow experience. Prior studies have suggested that only a limited number of games are enjoyable for elderly people,[4,19] but we can at least say that flow achieved through feeling competent is an important part of the gaming experience for them.

This study analyzed game form and age effects on usability, arousal, and gameplay experience. Currently, although brain-training games are hailed as successful drivers of mental health for elderly people, and researchers argue that they can increase math skills of schoolchildren,[1] the delivery of those training games in digital form does not improve players' effectiveness or efficiency, regardless of age. However, the digital game form makes the tasks more exciting and induces a heightened sense of flow in gamers of all ages. To answer our initial question, it makes a positive experiential difference for elderly individuals when solving logic problems within digital games, and hence, this new gaming technology may indeed be a blessing for an aging Western civilization.

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