Facilitating Mind-Wandering Through Video Games

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Abstract. Mind-wandering, i.e., letting the mind drift away from the task at hand, is mostly seen as a state of mind to avoid, as it may negatively impact the current task. However, evidence in cognitive science shows that mind-wandering can also positively affect creativity and problem-solving. Still, there is a lack of technological solutions to facilitate and utilize mind-wandering in such a specific way. In this short paper, we present MuseFlow, a video game designed to facilitate mind-wandering deliberately. Our study shows that MuseFlow induces mind-wandering significantly more often compared to a demanding game condition while maintaining the players' motivation to play and succeed in the game.

Keywords: mind-wandering, creativity, problem-solving, game mechanics, video game, creativity support tools, serious games

1 Introduction And Motivation

1.1 A Subsection Sample

Creativity is the ability to generate novel and useful ideas, for example as a means to solve problems with unusual solutions [5, 37]. Likewise, creativity is a valuable asset when attempting to solve individual and social issues [4]. There are some analog techniques to unlock it such as outdoor walking [16] or sleeping [34], both activities which try to involve the mind in task-unrelated thoughts. Such task-unrelated thoughts, often referred to as mind-wandering or daydreaming [26], are a mental phenomenon in which attention is reallocated from the task at hand to unrelated-thoughts without leaving the task [28, 2, 38]. Among others, Baird et al. [3] were able to show strong indications for a positive direct connection between mind-wandering and creativity. They furthermore found that the effect of mind-wandering is larger when invoked through an undemanding task compared to a demanding task or even compared to resting. Seli et al. showed that people can modulate their mind-wandering during an undemanding task as long as they can anticipate the upcoming challenges [21].

In this paper, we present the first results of a research endeavour, which aims at transferring these research insights into a usable everyday tool. As such, we developed MuseFlow, a video game that aims at facilitating mind-wandering using

undemanding game mechanics while keeping the participants still engaged. In this short paper, we present the Museflow game design based on game mechanics we identified as potentially undemanding. We conducted a study to investigate if MuseFlow induces mind-wandering significantly more often compared to a demanding game condition, while not negatively affecting the players' motivation to play and succeed in the game.

2 Related Work

2.1 Mind-Wandering

Mind-wandering also known as task-unrelated thought [28], self-generated thought [1], stimulus-unrelated thought [31], absent-mindedness [7] or daydreaming [25] is a cognitive phenomenon in which the attention is assigned to inner thoughts while performing an external task. Evidence indicates that mind-wandering is present between 30 and 50 percent of our waking life [11]. In the literature there are some hypotheses about *how* mind-wandering occurs. One of the most featured is the Meta-Awareness Hypothesis, which proposes that mind-wandering is the result of a temporal dissociation of meta-awareness, i.e., a lack of monitoring one's mind, which can happen even during tasks that one regards as important [20]. Although there is no a definitive explanation about *why* mind-wandering happens, there are some factors that can affect the occurrence of mind-wandering, such as: tiredness [35], task difficulty [22] and working memory capacity [11].

2.2 Incubation effect

The incubation effect refers to putting an unsolved problem aside for a period of time and returning to it later, making it easier to find a solution to it. [36, 8]. In a meta-analytic review, Sio et al. found a greater positive incubation effect when people perform an undemanding task during the incubation interval than when people are involved in resting or in demanding tasks [27].

One example of the relation between the incubation effect and mind-wandering is the study "Inspired by Distraction: Mind Wandering Facilitates Creative Incubation" of Baird et al. [3]. In this study, the authors used the creativity task called Unusual Uses Task (UUT) [10] to measure divergent thinking. In this task, the participants had to provide as many unusual uses as possible for an everyday object, like a pencil, for two minutes. Then, they immediately had to put it aside for twelve minutes. During this incubation interval, participants had to carry out one of the following conditions: perform a demanding task, perform an undemanding task, or sit quietly while taking a break. When the incubation interval finished, the participants went back to the same UUT problem and worked again for two minutes. The study showed that the group who performed the undemanding task exhibited the highest improvement rate in the postincubation, suggesting that mind-wandering caused by the undemanding task facilitates creative thinking.

3 MuseFlow Game Design

MuseFlow is a video game deliberately designed to facilitate mind-wandering and keep the players motivated. In this game, the player moves a ball horizontally across the moving bars. The game is over when the player gets a flag after crossing multiple platforms towards the right (see Fig. 1). The following are the four main game mechanics that define MuseFlow:

- `Predictability and Segmented Interaction:` Seli et al. demonstrated that people could modulate their mind-wandering during an undemanding task, especially when the upcoming challenges can be anticipated. Indeed, in that study it was shown that participants pressed a button and then were able to continue mind-wandering in the order of seconds, due to the anticipation signal of a timer [21]. In MuseFlow, the bars move up and down periodically with a constant speed, it makes the players wait and anticipate the right moment to press the button and jump to the next bar (Fig. 1A).
- `Absence of competition:` Although competing against other players and getting more assets during a video game are essential parts of a video game [19], some of them do not use these properties. For instance, Proteus [9], Playne [24] and Journey [32] use the progression and exploration of virtual worlds to engage the players. We defined MuseFlow as a non-competitive single player experience. The scorecard on the top right only shows the number of crossed platforms.
- `Absence of a failure:` Similarly, penalties such as going back to the beginning of the level or decreasing the amount of health of the main avatar are common punishments after making mistakes gaming. There are also video games such as The Longing [23], Dear Esther [33] and Pause [6, 17] that lack these failure properties. For example, in The Longing the avatar should cross between rooms and waits until the king awakens without any risk of failure or any penalty. In MuseFlow, there is no risk of failure during the game; even when the ball falls in a gap (e.g. Fig. 1C), immediately the system restart the ball on the previous bar without any penalty
- `Simple controls:` This concept is related to the fact that mind-wandering is associated with a low level of task difficulty [21] and with the tendency of mind-wandering when performing a practiced task [14]. For this purpose, we limit MuseFlow to use only the left and right arrows to play the game.
- `Visual Appearance:` MuseFlow uses a minimalist and geometric aesthetics with a black background in order to avoid extra stimuli.

Overall, the game should be an undemanding experience that can induce mind-wandering in the player while still keeping them motivated. In order to study this, we developed a second version of the game as a demanding condition. This included two fundamental changes:

- `Increased Game Speed`: In the demanding condition platforms moved on average 5.3 times faster. This resulted in less waiting time as well as requiring more attention in order not to miss a platform.

– `Increased Challenges`: Gaps between platforms were introduced that required players to precisely find the point in motion when to move the ball towards the next platform so it does not fall in the gap

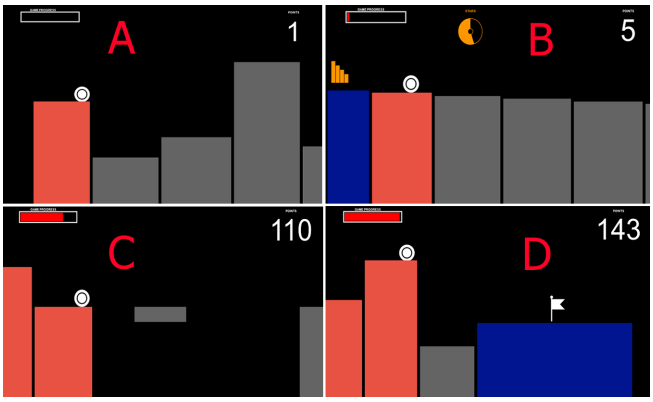

Fig. 1. The game prototype. The player character is represented by the white ball. The rectangular bars are the platforms that move up and down - traversed platforms turn red.

A composite image of four game screenshots. The game looks like this: A black background with grey bars in the foreground that represent the platforms - it looks like a bar chart. A white ball is positioned on the leftmost platform. There is a game progress bar at the top left and a Score counter in the top right. 4A: Shows the start of the game with the ball sitting on the first platform. 4B: On the far left, there is an Orange stair symbol which represents the Stair power-up. The white ball is past the power-up and in front of it, the bars have taken on a down-ward stair structure. 4C: The ball is waiting in front of a gap. A floating platform is coming from the right. 4D: On the far right there is the final platform colored in blue with a white flag on top of it.

4 Study Method and Design

To evaluate if and how the MuseFlow game would be able to facilitate mind-wandering, we conducted a remote study with 36 participants (13 female, 23 male). The 2020 Covid-19 pandemic led to the decision to run the study remotely and not in a lab. We used the online platform Survey Circle [30] to recruit participants. The age ranged from 20-44 years old, with one participant being older than 60 and the median age group being 25-29 years. Most participants were from central Europe. We did not request further details from participants to follow the GDPR principle of data economy. We applied a between-subjects design with the type of game (Undemanding, Demanding) as independent variable.

4.1 Dependent Variables & Measures

- Daydreaming Frequency Scale (DDFS): In order to measure the general mind-wandering propensity of our participant sample and based on existing literature [3], we applied the DDFS questionnaire from the Imaginal Process Inventory (IPI) [26, 29]. The DDFS produces a score between 12 (low propensity) and 60 (high propensity).
- Thought Probes: A Thought Probe is a typical measure of mind-wandering activity and comparable to Experience Sampling techniques [18]. Adapted from the literature ([12, 13, 15, 21]), we prompted the user during the game with a pop-up question "Just now, where was your attention?" with a 6-point scale from "on task" (1) to "off task" (6). For scores above 3, this Thought Probe was tagged as a mind-wandering episode. Overall, five Thought Probes were distributed evenly across the game experience.
- From the Dundee Stress State Questionnaire (DSSQ) - TUT: we applied the Task-irrelevant Interfence from part 4 (Thinking Content) of the DSSQ, which is also referred to as task-unrelated thinking (TUT) in the literature. This is a retrospective measure for mind-wandering activity that was also used in related work [3]. It presents participants questions about specific examples of off-task thoughts. We wanted to understand if MuseFlow would also induce longer-lasting off-task thoughts that participants would still be aware of after playing the game. The DSSQ-TUT produces a score between 8 (no task-unrelated thinking) and 40 (high task-unrelated thinking).
- From the Dundee Stress State Questionnaire (DSSQ) - Motivation: This part from the DSSQ (with sub-scales for Intrinsic and Success Motivation) was used as a measure to analyze how engaged participants were in playing the game. The DSSQ-Motivation scales each produce a score between 7 (low motivation) and 35 (high motivation). The results should indicate if there is a difference in motivation between MuseFlow and the demanding game condition, i.e. if the undemanding game characteristics had a negative impact on the overall motivation.
- Missed Opportunities: To check if our two game versions did indeed differ in terms of demand, we logged the number of times a participant could have moved on to the next platform but hesitated or oversaw that opportunity. This number should consequently be higher for the Demanding condition of the game, which moves much faster.

4.2 Procedure

Participants were randomly and evenly assigned to one of the conditions, based on the internal ID they received on the SoSci Survey platform. After filling out the consent form and the demographic questionnaire, participants were politely asked turn off their mobile phones and not engage in any activities outside the game. A short description explained the controls of the game and the overall goal as moving the ball towards the right until a flag signals the end of the game. Following that, the participants would play the game until completion (ca. 10

minutes). During that time, at five separate set intervals, the game would be paused and a Thought Probe would pop-up with a 6-point scale, asking the participant whether their current thoughts were "on task" (1) or "off task" (6) [13]. Upon answering, the dialogue would close and the game would resume. When the participant reached the flag, the game ended and participants would be forwarded to the two DSSQ scales, followed by the DDFS (ca. 9 minutes). The overall duration was around 19 minutes.

5 Results & Discussion

As our data, while being of metric scale, was mostly not normally distributed, we decided to analyze it through the means of non-parametric test statistics.

First, we take a look at the DDFS results to understand the mind-wandering propensity in our participant sample. The descriptive data shows that mind-wandering propensity is slightly above average (40, DDFS range: $12 - 60$) but similar for both groups (Undemanding $m = 39.39; SD = 10.80; Md = 40$ and Demanding $m = 40.22; SD = 10.87; Md = 44$). Accordingly, the Mann-Whitney-U does not show any significant differences ($z = -0.143; p = 0.887; N = 36$).

Looking at the number of missed opportunities, participants on average missed many more opportunities during the Demanding condition of the game (see Table 1). This difference is statistically significant as shown by the Mann-Whitney-U test ($z = -4.619; p < 0.001; N = 36$). As a result, we can conclude that our goal of creating a demanding version of MuseFlow was successful.

Next, the DSSQ motivation scales (range $7 - 35$) tell us that the two experimental groups did not significantly differ in terms of their intrinsic and success motivation to play the game (see Table 1). Accordingly, these results suggest that the mind-wandering characteristics of the Undemanding MuseFlow game did not reduce motivation to play the game.

Table 1. The average and mean scores for the DSSQ Motivation and TUT scale, Missed Opportunities and the average and median number of mind-wandering episodes per participant (Thought Probes).

DSSQ-Motivation and Missed Opportunities					
Condition	Measure	n	Mean	Median	SD
Undemanding	Missed Opp.	18	1.17	0.00	4.22
	DSSQ Intrinsic Mot	18	18.89	19.50	4.13
	DSSQ Success Mot	18	18.89	17.00	5.80
	DSSQ-TUT	18	14.89	15.00	5.03
	Thought Probes	18	1.72	1.00	1.60
Demanding	Missed Opp.	18	15.33	13.50	9.16
	DSSQ Intrinsic Mot	18	20.33	21.50	3.29
	DSSQ Success Mot	18	17.78	16.00	7.13
	DSSQ-TUT	18	14.83	13.50	3.03
	Thought Probes	18	0.44	0.00	1.04

Addressing our main research question, whether the game design was able to induce mind-wandering episodes in participants, we have two different measures. Starting with the Thought Probes, we counted the number of mind-wandering episodes for each participants. As such, we regarded each probe with a $score > 3$ on the $6 - point - scale$. Only Probes $2 - 5$ were taken into account as Probe 1 was meant to get participants accustomed to this type of measurement. The descriptive data suggests that the Undemanding condition ($m = 1.72$ episodes) led to more mind-wandering episodes compared to the Demanding condition ($m = 0.44$ episodes; Table 1). Accordingly, the Mann-Whitney-U test shows a significant difference between the conditions ($z = -0.291; p = 0.04; N = 36$). The histogram shows that 14 participants in the demanding condition did not report any mind-wandering episodes at all and only 1 participant experienced 3 or 4 mind-wandering episodes compared to 7 in the MuseFlow undemanding condition (see Figure 2).

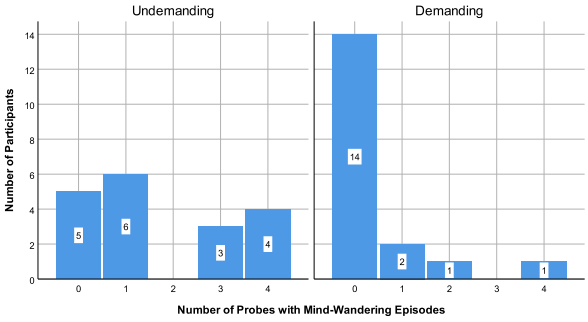

Fig. 2. The distribution and frequency of mind-Wandering episodes across the two conditions

The Thinking Content Scale of the DSSQ (DSSQ-TUT: range $8 - 40$) does not show any significant differences between the groups (Mann-Whitney-U test: $p = 0.89$). Descriptive data shows that both conditions seemed to induce the same and relatively low amount of such long-lasting task-unrelated thoughts (Table 1). We conclude that the MuseFlow game is currently not capable to induce the type of task-unrelated thoughts that participants can later attribute to coherent thoughts and ideas.

6 Limitations

As an exploratory research into a new field, we would see most limitations as inspiration for future research. For example the inconclusive results regarding the amount of mind-wandering activity between the Thought Probes and the DSSQ-TUT scale hints that there are different levels of mind-wandering and it may be

important to better understand how to evoke which level. As a remote study, we were not fully in control of any external factors that may have influenced our results. We designed the study as a rather short and concise experience to limit such effects. Future research should still aim to replicate these results in a lab environment.

7 Conclusion and Future Work

Inspired by the research of Baird et al. [3], who suggests mind-wandering can be beneficial for creative problem solving, we designed MuseFlow, a game that is deliberately designed to facilitate mind-wandering. In our study, we compared MuseFlow to a more demanding version of the game. Our results show that MuseFlow was indeed able to induce significantly more mind-wandering episodes compared to the demanding condition without showing a decrease in participants' motivation to play the game. However, the mind-wandering episodes measured through Thought Probes are not reflected in the retrospective DSSQ-TUT measurement. We conclude that these mind-wandering episodes are therefore rather short and volatile. This can be attributed to the game design, which allowed participants only to briefly abstain from the task, not allowing for more coherent off-task thinking and long term mind-wandering. We are not aware of existing research that would allow to make inferences regarding what kind of mind-wandering is necessary to facilitate problem solving and creativity. Therefore, these results require more research regarding the nature of mind-wandering episodes.

Overall, this work is a first step to better understand this relatively new field of research by investigating the processes and interaction mechanics which might induce mind-wandering. Our future work will in particular focus on analyzing the impact on creative problem solving that can be achieved through such game experiences. For that, we will also elaborate the game design, for example by increasing the motivational aspects, and the influence of different game mechanics on mind-wandering. The MuseFlow code is available as Open Source on https://github.com/JuanOlaya/MuseFlow and we invite interested researchers to contribute to this endeavor.

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