Examination of distributed learning on recent and remote memory using in-person and online experimental paradigms.

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Abstract

Learning is crucial in everyday life. However, how much information we retain depends on the type and schedule of training. It has been widely acknowledged that spaced learning holds a distinct advantage over massed learning for cognitively healthy adults and should be considered an educational standard, particularly when consolidating long-term memory. Given that many experiments have been required to be conducted online as a result of social-distancing regulations during the Covid-19 pandemic, we examined whether the spacing advantage could be replicated in an online setup. Two experiments were conducted to examine the effects of spacing across recent (24 hours) and remote (one-month) retention intervals using the Face-Name Pairs task either in-person (Experiment 1) or online (Experiment 2). The results of Experiment 1 suggest that the beneficial memory effects of spaced training are particularly observed with remote memory. The results of Experiment 2 suggest that although participants learn and recall better in an online setup compared to in-person, the spacing effects were not as robust and did not confer any real advantage. These results are discussed in terms of advantages and disadvantages of the two procedures and the implications for online studies.

Key words: Spaced learning, distributed practice, massed learning, long-term memory, retention, online experiments.

Introduction

It has been widely acknowledged that spaced learning (repeated learning sessions distributed over time) holds a distinct advantage over massed learning (learning is “crammed” into a shorter timeframe, Vlach et al., 2008; Benjamin & Tullis, 2010; Kapler et al., 2015; Delaney et al., 2018). The spacing effect has been widely reproduced across many domains (Goverover et al., 2009; Breckwoltd et al., 2016; Wang et al., 2017). For example, Kapler, et al. (2015) found that undergraduate students who reviewed lecture material after an interval of multiple days (spaced learning) performed better on tests than those who reviewed the content after only one day. Similarly, research has shown that spaced learning also benefits the retention of practical skills at two-weekly and one-yearly intervals in surgical trainees (Spruit et al., 2014). The findings are so robust that Kapler et al. (2015) have suggested that repeated sessions should be considered as an educational standard. Despite this, individuals consistently rely on massed schedules of learning over spaced, even going so far as to formally judge massed learning as better than spaced when presented with alternative evidence (Kornell & Bjork, 2007; Kornell, 2009; Son & Kornell, 2009). This may be due to the fact that massed learning seems less time-consuming than spaced (Baddeley & Longman, 1978).

In particular, the effects of spaced learning are thought to be preserved over longer retention intervals (Glenberg & Lehmann, 1980; Bahrnick et al., 1993). For example, Simanton & Hansen (2012) evaluated the ability of medical students to retain relevant knowledge across four years depending on the use of different educational models. Their results suggest that clinical application and spaced training schedules may lead to better retention of medical knowledge over a four-year period. These results complement those of Spruit et al. (2014), mentioned above. Similarly, Sobel et al. (2011) found that one-week spacing produced better long-term retention of unfamiliar English words compared to one-day massed learning after a five-week interval. In one particularly interesting study, Price Kerfoot et al. (2010) divided

urology residents into online spaced training and web-based teaching (massed) schedules, whereby students received information to be studied at scheduled daily intervals, or all together in one single email. Participants were then tested periodically over a forty-five-week period. Results indicated that although participants in the massed condition tended to perform better in the short-term (weeks fourteen to sixteen), participants in the spaced condition demonstrated significantly better long-term retention of material (weeks eighteen to forty-five). These findings suggest that spacing may not be particularly beneficial in the short-term but can lead to significant long-term retention over greater periods of time (Price Kerfoot et al., 2010). This could also explain why many individuals believe that massed learning is preferable to spaced.

The recent outbreak of the coronavirus SARS-CoV-2 (COVID-19) has had an extraordinary impact on research. Due to ongoing national lockdowns, laboratory work was forced to an abrupt halt, resulting in the suspension, termination, and discontinuation of many important experiments (Weiner et al., 2020; Alam et al., 2021). Additionally, due to current public safety measures, researchers are unable to convene with participants face-to-face unless maintaining essential and/or life-saving care, or conducting research directly related to COVID-19 (GlobalData Healthcare, 2020; Ranganathan et al., 2020). As a result, researchers working with human participants have had to consider alternative methods of recruitment and supervision of research participants, for example, moving experiments online (Goldsack et al., 2020; Sohrabi et al., 2021).

There are a number of advantages to conducting research online. For example, online experiments can benefit from a greater number and wider range of participants, allowing for more robust and generalisable datasets (Langer & Beckman, 2005; Comley & Beaumont, 2011b). Remote research can also prove less time-consuming for researchers and allow greater

flexibility for participants (Comley & Beaumont, 2011a), i.e. allowing participants to select their own time and place to take part in a study. Furthermore, online methods are becoming increasingly relevant in a digital world (Germain et al., 2018). That being said, remote experiments also raise a number of issues, such as controllability, ethical concerns, sample bias, and a heightened possibility of misunderstandings when explaining a task (Comley & Beaumont, 2011a; Comley & Beaumont, 2011b; Bridges, 2016; Page Hocevar, & Flanagan, 2017; Claypoole et al., 2018; Germain et al., 2018).

With regard to distributed learning, there is ever-expanding literature based around spacing practice and its relationship with online education. There is much research to suggest that the spacing effect is evident in distance/online learning as well as face-to-face and can in fact be optimised by the use of online techniques (Price Kerfoot et al., 2010; Carvalho et al., 2020; Jost et al., 2021). For example, Marzouk et al. (2016) suggest that spaced learning of definitions can be optimised using online tools, including using a glossary that prompts students to reflect on the context in which they last encountered a specific definition and scheduling optimal review times based on close monitoring of student's online study activity. Similarly, Fulton et al. (2013) found that the spacing effect is evident at shorter and longer retention intervals when taking an online statistics course and suggested that students and distribution of practice could benefit from frequent deadlines imposed through the online course.

There is an ongoing replication crisis relevant to psychological research, whereby researchers often struggle to reproduce the results of past studies (Maxwell et al., 2015; Morawski, 2019). With this in mind, it is important to investigate whether this replication crisis extends to adapting experiments for online participation. There is evidence to suggest that some online replications are successful. For example, Claypoole et al. (2018) managed to successfully replicate the results of Thomson et al. (2016), suggesting that laboratory vigilance

tasks can be adapted for online use. However, they also provide a number of cautions, implying that the results are dependent on type and length of task, among other factors (Claypoole et al., 2018). Conversely, there have been a number of failed attempts at online replication. Cusak et al. (2012) failed to replicate the results of Burgmer & English (2012) both directly and after adapting a word-search task (originally created by Chen et al. (2001), used in Burgmer & English's second experiment) for online use. Similarly, Plant (2016) suggests that the ongoing replication crisis may be a direct result of a move to computer-based tasks.

In two experiments, we examine the effects of distributed learning on recent and remote learning using a Face-Name association task. Experiment 1 was conducted in-person in a controlled laboratory setting, while Experiment 2 was conducted online. Overall, we hypothesise that benefits of a spaced learning paradigm, particularly at remote time intervals, would be observed in both in-person and online experimental conditions.

Experiment 1:

Brief introduction

While spaced effects are observed across many domains, many of the aforementioned studies tend to focus on recent memory, as well as relying on similar types of stimuli during learning. For example, most involved the learning of nonverbal sequences, names of objects, and/or word pairs (e.g. Cull, 2000; Hochhalter et al., 2005; Logan et al., 2005). However, there is limited research as to whether spacing is effective when learning more abstract concepts, such as personal names. This is an important consideration, as retention of names becomes a key difficulty with Alzheimer's disease (AD) and other age-related disorders (Hromas & Bauer, 2019). Further, Reason & Lucas (1984) and Cohen & Faulkner (1986) demonstrated that individuals find it more difficult to recall names than occupations or hobbies. We have chosen

to use a face-name association task as this task is more abstract and more ecologically valid. In this experiment, we examine face-name retention at both recent and more remote time intervals (24 hours, 1 week and 1 month) in young adults that have been either spaced or massed trained. This experiment is done in a controlled laboratory setting. We hypothesise that spaced learning will preserve memory primarily at long-term intervals.

Methods

Participants

One-hundred-and-eighteen participants (60 males, 58 females) aged 18-25 (mean = 23.08, standard error of the mean (SEM) = 0.77) participated in the experiment. Participants were recruited via advertisements and were not compensated. An exclusion and inclusion criteria were used before recruitment, so all participants were healthy, cognitively healthy, and had normal or corrected-to normal vision. No participant had a known history of drug or substance abuse, and no other relevant medical conditions. Prior to the experiment, power calculations (G*Power) were conducted to assess the minimum number of participants that would be required for each condition; using $p = 0.05$, effect size of 0.3 and power of 0.9 calculations suggested a minimum of 15 participants per group.

Materials

Three control tasks were used to ensure that both training groups (massed & spaced) were similar in terms of cognitive functioning, such as IQ, executive functioning, and general memory ability: The National Adult Reading Test (NART; Nelson, 1982) gave an estimate of verbal IQ, the Trail Making Tasks (TMT; Reitan & Wolfson, 1992) tested executive

functioning, and the Rey Auditory Verbal Learning Test (RAVLT; Rey, 1941) evaluated memory and learning strategies. The Face-Name Pairs task was used to assess associative memory and was carried out using a Sony laptop. Eight female faces (black and white photograph without hair) with associated names were presented twice in a block; there were 4 acquisition blocks in total (see Zeineh et al. (2003) for similar stimuli set and procedure). Each face-name pair was presented on screen for 5 seconds. The 4 blocks were either presented sequentially on the same day (massed condition, $n = 57$) or 1 block of face-name pairs was presented each day for 4 days (spaced condition, $n = 61$). After each block, retention was assessed. Retention consisted of the eight faces presented once without their corresponding name. The number of correctly recalled names associated with each of the eight faces (out of 8) was used to measure memory performance.

Procedure

Participants were initially presented with a consent form to be read and signed. The experiment took place in a quiet room, free of distractions. Participants were asked to complete the NART, TMT, and RAVLT prior to partaking in the experiment. Participants were randomly assigned to either the spaced or massed group and then to a 24 hour, 1 week, or 1 month recall condition. Each condition included four study blocks and one recall block. Participants were asked to watch a video of eight faces paired with eight names and were to recall the names associated with each face. It was explained that each trial consisted of two videos, a study block video shown twice per trial, and a retention block video. Participants in the spaced group completed the four blocks over four consecutive days. Participants in the massed group completed the four blocks on one day. Those in the 24 hour condition completed a single recall block twenty-four hours after completing the study block, those in the 1 week condition completed the recall

block one week after completing the study block, and those in the 1 month condition completed the recall trial one month after the study block (see Figure 1 for details, N/condition/group and breakdown by gender. As much as possible, there were equal numbers of males and females in each category).

1a.

1b.

Figure 1: A visual representation of the experimental design and a breakdown of the massed (1a) and spaced (1b) conditions including the n/group (experiment 1).

Statistics

Microsoft Excel and an IBM SPSS statistics software programme (version 23) were used to calculate the results. Mixed and between factorial ANOVAs were used to compare the learning and recall phases, respectively. Tukey HSD test was used for between group *post-hoc* comparisons and Bonferroni corrected t-tests were used for further within-group comparisons. Independent and paired samples t-tests were used where appropriate. Results were determined as statistically significant when $p < 0.05$.

Ethics

The Psychological Society of Ireland codes of ethical conduct were observed throughout. Participants were provided with an information sheet in advance of the experiment, explaining the procedure in detail. All participants were over eighteen, consented to taking part, and were informed that they could withdraw at any time. Data were anonymised for privacy. All experiments were approved by Maynooth University ethics committee (reference BSRESC-2019-2378730).

Results

To ensure that both massed- and spaced-trained groups were matched across age, general IQ, spatial and executive functioning, and memory, we used independent-samples t-tests to compare participants from both groups with respect to age and scores on the NART, TMT, and

RAVLT, respectively (see Table 1). The results indicate that there was no significant effect of age ($t(116) = -0.157, p = 0.876$), NART score ($t(111) = -1.130, p = 0.261$), TMTb-a score ($t(111) = 0.426, p = 0.671$), and RAVLT score (trials 1-5) ($t(111) = -0.573, p = 0.568$), suggesting that participants were cognitively-matched and that further results were not affected by these variables.

Table 1: Mean age, NART, TMT, and RAVLT scores (standard error of the mean) for both spaced and massed conditions, and their p values.

	N	M/F	Age	NART	TMTa	TMTb	TMTb-a	RAVLT
Spaced	61	31/30	23.36	24.27	25.00	45.88	20.84	52.71
(SEM)			(1.20)	(1.67)	(0.77)	(2.11)	(2.14)	(1.02)
Massed	57	29/28	22.86	23.47	24.18	46.44	22.30	50.60
(SEM)			(1.02)	(1.64)	(1.18)	(1.98)	(1.73)	(1.07)
p values	-	-	0.650	0.735	0.559	0.846	0.596	0.155

Acquisition Phase

An initial 2 X 4 mixed between-within factorial ANOVA was conducted to compare learning across the four trials (blocks) for both the spaced- and massed-trained groups. A significant main effect of Trial ($F(3, 114) = 164.176, p < 0.001$, partial eta squared = 0.812) was found, Tukey *post hoc* tests showed that participants on Trial 4 learned more than Trial 1 ($p < 0.01$). There was no effect of Group ($F(1, 116) = 2.322, p = 0.130$, partial eta squared = 0.020). There was also no significant interaction between Trial and Group ($F(3, 114) = 0.393, p = 0.758$, partial eta squared = 0.010) (see Figure 2a).

Figure 2a: Mean number of correct names (and standard error of the mean, SEM) for both spaced and massed conditions across the 4 learning blocks.

Retention Phase

A two-way between groups ANOVA was conducted to explore the difference between the ability of those in the spaced and massed groups to recall the face-name pairs following an interval of 24 hours, 1 week, or 1 month. The results indicate a main overall effect of Group (spaced/massed) ($F(1, 112) = 9.464, p = 0.003$, partial eta squared = 0.078), with the spaced group recalling more compared to the massed group. There was a significant main effect of Retention interval ($F(2, 112) = 14.673, p < 0.001$, partial eta squared = 0.208). There was no significant interaction effect ($F(2, 112) = 0.619, p = 0.540$). Three Bonferroni corrected t-tests were conducted to further explore the differences in retention between each group. The results indicate that there was no significant difference between the spaced and massed groups performance on the retest at 24 hours ($t(56) = 1.706, p = 0.094$), and 1 week ($t(28) = 1.045, p$

= 0.305). However, there was a significant difference between the spaced and massed groups performances on the retest at 1 month ($t(28) = 3.108, p = 0.004$) (see Figure 2b).

Two one-way ANOVAs were conducted to examine whether there were any differences between the performance of participants in the spaced and massed conditions respectively at the three different time intervals. Results for the **spaced group** indicated that there was an overall significant difference for three retention intervals ($F(2, 58) = 5.110, p = 0.009$). Tukey HSD *post-hoc* comparisons indicated however that performance for the spaced group was not significantly different between 24 hours and 1 week ($p = 0.183$) but was significantly different between recall at 24 hours and 1 month ($p = 0.009$). There was also no significant difference between performance at 1 week and 1 month ($p = 0.505$). Similarly, the results of the **massed group** indicated that there was a significant difference between performance at each of the three intervals ($F(2, 54) = 10.482, p < 0.001$). *Post-hoc* comparisons indicated that performance for the massed group was significantly different between 24 hours and 1 month ($p < 0.001$), and significantly different between 1 week and 1 month ($p = 0.026$). There was no significant difference between performance at 24 hours and 1 week ($p = 0.281$).

Figure 2b: Mean retention score (and SEM) for both the spaced and massed groups when re-tested at twenty-four hours, one week, and one-month post learning.

Brief Discussion

These results would suggest that with spaced training there is a small initial decline in memory performance after 1 week but a limited decline after this; whereas with massed training there is a gradual decline in performance throughout the month, and particularly between 1 week and 1 month. The beneficial memory effects of spaced training are particularly observed with long-term memory (i.e. 1 month). Our results are in line with the original hypotheses, and other studies (Vlach, et al., 2008; Goverover, et al., 2009; Benjamin et al., 2010; Kapler, et al., 2015; Breckwoltd, et al., 2016; Wang, et al., 2017; Delaney, et al., 2018). In particular, these results are somewhat similar to those of Price Kerfoot et al. (2010), who found that participants in the massed condition performed better than those in the spaced condition at shorter time intervals, but at longer time intervals, those in the spaced condition retained significantly more information than those in the massed condition. Having established that spacing optimises retention in adults using a Face-Name Pairs task, it raises the question of whether this effect can be replicated in an online procedure?

Experiment 2

Brief Introduction

The recent outbreak of COVID-19 has forced researchers to adapt accordingly. In many cases, this involves adapting existing experiments so that they may be conducted online rather than in-person (Ranganathan et al., 2020; Alam et al., 2021; Sohrabi et al., 2021). There are a

number of benefits and pitfalls to consider when conducting research online, such as convenience, the possibility of a more inclusive and generalisable dataset, access to technology, and ethical concerns (Comley & Beaumont, 2011a; Comley & Beaumont, 2011b; Surkhali & Garbuja, 2020; Zeng, 2020). Furthermore, it is important to investigate whether well-established findings, such as the spacing effect, can be replicated when experiments and tasks are adapted for online use, given the different medium and potential access to a greater participant pool (Comley & Beaumont, 2011b; Plant, 2016; Chmielewski & Kucker, 2020). Given the direct effect of the recent pandemic, a number of changes were made to the current research project. Most significantly, the Face-Name Pairs task administered in Experiment 1 was adapted for use online via Qualtrics. This begs the question of whether the results of the previous experiment can be replicated when the task is administered remotely rather than in-person? In this experiment, we use an adaptation of the Face-Name Pairs task to examine recall at both recent and remote time intervals (24 hours and 1 month) in adults that have been either spaced or massed trained. We hypothesise that spaced learning will preserve memory primarily at long-term intervals, as in Experiment 1.

Methods

Participants

The sample consists of 358 participants (155 males and 253 females). Participants were aged between 18-72 (mean = 26.87, standard error of the mean (SEM) = 2.34). Participants were recruited via advertisements and were not compensated. An exclusion and inclusion criteria were used before recruitment; no participant had a known history of drug or substance abuse, and no other relevant medical or psychological conditions. All participants self-reported as being healthy, cognitively healthy, and had normal or corrected-to-normal vision.

Materials & procedure

The same Face-Name Pairs task that was used in Experiment 1 was carried out using the online survey platform Qualtrics (<https://www.qualtrics.com/>). Upon reading an information sheet and agreeing to participate, participants were given a Qualtrics link via email. Participants were initially presented with a digital consent form stating that all personal data would be anonymised and kept completely confidential; participants were allowed to continue to the experiment once they indicated this on the survey. As in Experiment 1, there was a learning phase and a recall phase. For the learning phase, participants were requested to watch a slideshow of eight face-name pairs, each pair was left onscreen for 5 seconds and presented twice in random order. Participants were then required to recall and type in each of the eight names when presented with the face alone. This was repeated four times (see Experiment 1). Participants were randomly assigned to a massed or spaced group and then to a 24 hour or 1 month recall group. Participants in the massed group ($n = 179$; 85 male/94 female) were presented with the 4 learning blocks sequentially on a single day and then were required to recall the correct name when presented with faces only, either 24 hours later ($n = 90$) or 1 month later ($n = 89$). Participants in the spaced group ($n = 179$; 70 male/109 female) were presented with the 4 learning blocks across 4 days (the survey was sent to participants at the same time each morning). The same participants were then required to recall the correct name when presented with the faces only, again either 24 hours later ($n = 98$) or 1 month later ($n = 81$). Note we dropped the 1-week retention interval for this experiment both for ease of administration and that results from Experiment 1 suggested the main spacing effects were observed at longer term intervals (i.e. 1 month recall). In addition, as many of the cognitive tasks administered in Experiment 1 require in-person contact (e.g. TMT, RAVLT) we only included one online control task – the cognitive failures questionnaire (CFQ, Broadbent et al.,

1982). The CFQ is often used as a general measure for attention, general memory and general cognitive issues (Wallace et al., 2002).

Statistics

Microsoft Excel and an IBM SPSS statistics software programme (version 23) were again used. An initial 2 X 4 mixed between factorial ANOVA was conducted for the learning phase. A two-way between-groups ANOVA was conducted to examine differences between groups (massed and spaced) for each retention time (24hrs and 1-month). Bonferroni corrected t-tests were used for further within-group comparisons. Independent t-tests and dependent t-tests were used where appropriate.

Ethics

The American Psychological Association and Psychological Society of Ireland codes of ethical conduct were observed throughout. Participants were provided with an information sheet in advance of the experiment, explaining the procedure in detail. All participants were over eighteen, consented to taking part, and were informed that they could pull out at any time. Data were anonymised for privacy. All online experiments were approved by Maynooth University ethics committee (reference BSRESC-2019-2378730).

Results

An initial comparison of age indicated that participants assigned to the massed learning group were slightly but significantly older (mean = 29.4 (SD=13.1)) than those assigned to the spaced group (mean = 24.1 (SD=8.8); $F(3, 354) = 19.6$, $p < 0.001$, partial eta squared = 0.053). Analysis of the CFQ results however revealed no difference between the two groups (massed

mean = 41.8 (SD =15.1) and spaced mean = 41.7 (SD=13.1); $F(3, 354) = 0.008$, $p = 0.929$, partial eta squared = 0.001).

Acquisition Phase

An initial 2 X 4 mixed between-within factorial ANOVA was conducted to compare learning across the four trials for both the spaced- and massed- trained conditions. There was a significant main effect of Trial ($F(3, 354) = 292.655$, $p < 0.001$, partial eta squared = 0.713), but no effect of Group ($F(1, 356) = 0.856$, $p = 0.356$, partial eta squared = 0.002). There was a significant interaction between Trial and Group ($F(3, 354) = 3.947$, $p = 0.009$, partial eta squared = 0.032) (see Figure 3a). Follow-up independent t-tests showed that there was no significant difference between the performance of the spaced and massed groups on Trial 1 ($t(356) = 1.517$, $p = 0.130$), trial 2 ($t(356) = -1.129$, $p = 0.260$), and trial 3 ($t(356) = -1.711$, $p = 0.088$), however the massed group performed significantly better than the spaced group on Trial 4 ($t(356) = -2.071$, $p = 0.039$).

Figure 3a: Mean number of correct names (and SEM) for both spaced and massed groups across the 4 learning blocks.

Retention Phase

A two-way between groups ANOVA was conducted to explore the difference between the ability of those in the spaced and massed groups to recall the face-name pairs following an interval of 24 hours or 1 month. The results indicate an overall main effect of Group (spaced/massed) that was just significant ($F(1, 354) = 4.079, p = 0.044$, partial eta squared = 0.011), with the spaced group recalling more correct names (mean = 4.8 (SD = 2.2)) compared to the massed group (mean = 4.3 (SD = 2.5)). There was also a significant main effect of retention interval ($F(1, 354) = 175.653, p < 0.001$, partial eta squared = 0.332), with recall at one-month significantly (mean = 3.1 (SD = 2.0)) less than 24 hours (mean = 4.6 (SD = 2.4)) as would be expected (see Figure 3b). There was no significant interaction effect ($F(1, 354) = 0.126, p = 0.723$). Two Bonferroni corrected t-tests were conducted to further explore the differences in retention between each group. The results indicate that there was no significant difference between the spaced and massed groups performance on the retest at 24 hours ($t(186) = 1.245, p = 0.215$) or 1 month ($t(168) = 1.587, p = 0.114$).

Figure 3b: Mean retention score for both the spaced and massed groups when re-tested at 24 hours and 1 month post learning.

Other factors

One difficulty with online experiments is that experimental control is often lost. In this respect, we noticed that there was a significant age and gender difference with respect to our participants. For example, the massed group was slightly older than the spaced group (mean = 29.4 and 24.1, respectively). In addition, there were more females in the spaced group whereas the massed group was more balanced in this respect (see above). Correlating age with retention scores, we found a small but overall significant negative correlation ($r = -0.117$, $p = 0.028$), with age having more of an impact in the spaced group ($r = -0.264$, $p = 0.001$) compared to the massed one ($r = 0.011$, $p = 0.887$).

When we examined whether gender had an impact on memory performance, we found an overall significant effect ($F(1, 350) = 17.99$, $p < 0.001$, partial eta squared = 0.049), with females showing better recall than males at both 24 hour (6.3 (SD = 1.8) and 5.5 (SD = 2,

respectively) and 1 month intervals (3.6 (SD = 2.1) and 2.5 (SD = 1.7, respectively). No Gender X Group (spaced/massed) effect was observed ($F(1, 350) = 0.301$, $p = 0.584$, partial eta squared = 0.001).

Direct comparison between in person and online experiments during learning and retention.

Using a 2 X 2 X 4 mixed factorial ANOVA for the learning phase (Figure 4a), we found an overall significant effect for Trial ($F(3, 1326) = 3.44$, $p < 0.001$, partial eta squared = 0.438), with participants on trial 4 (mean = 6.1 (SD = 1.7)) learning significantly more compared to trial 1 (mean = 3.0 (SD = 2.0); Bonferroni corrected t-t-test, $p < 0.001$). No overall significant difference between Group (massed vs spaced) was observed ($F(1, 442) = 2.44$, $p = 0.119$, partial eta squared = 0.006). There was however an overall significant difference in the experimental condition (online vs in-person; $F(1, 442) = 96.7$, $p < 0.001$, partial eta squared = 0.18), with participants in the online condition (mean = 5.6 (SD = 1.4) learning more than those in-person (mean = 3.9 (SD = 2.8)).

Figure 4a: Mean number of correct names (and SEM) for both spaced and massed and in-person and online groups across the 4 learning blocks.

For the retention phase we conducted a 3 way between groups ANOVA. We found an overall significant effect for retention interval (24 hr vs 1-month; ($F(1, 438) = 107.4, p < 0.001$, partial eta squared = 0.197)), with participants recalling on average less names after 1 month (mean = 2.9 (SD = 2)) compared to 24 hours (mean = 5.6 (SD = 2)). There was also a significant effect for Group (massed vs spaced; ($F(1, 438) = 12.6, p < 0.001$, partial eta squared = 0.028)), with participants in the spaced group recalling more names (mean = 4.8 (SD = 2.3)) compared to those in the massed group (mean = 4.1 (SD = 2.5)). Importantly, there is also an overall significant difference in the mode of experimentation (online vs in-person; ($F(1, 438) = 20.5, p < 0.001$, partial eta squared = 0.045), with participants online recalling on average more names (mean = 4.6 (SD = 2.4)) compared to those in-person (mean = 3.8 (SD = 2.2)) (see Figure 4b).

Figure 4b: Mean retention scores (and SEM) for both spaced and massed groups and in-person and online groups when retested at 24 hours and 1 month post learning.

Discussion

Findings from Experiment 1 show a strong effect of spaced learning at long-term intervals (1 month). This is in line with our original hypothesis, and other studies (Vlach, et al., 2008; Goverover, et al., 2009; Benjamin et al., 2010; Kapler, et al., 2015; Breckwoltd, et al., 2016; Wang, et al., 2017; Delaney, et al., 2018). In particular, these results are somewhat similar to those of Price Kerfoot et al. (2010), who found that participants in the massed condition performed better than those in the spaced condition at shorter time intervals, but at longer time intervals, those in the spaced condition retained significantly more information than those in the massed condition. This finding would suggest that at shorter intervals, the schedule of learning makes little to no difference in terms of overall performance and could potentially lend some insight as to why individuals are inclined to trust cramming over spacing (Kornell, 2009). If, at twenty-four hour or weekly intervals, participants actually perform just as well having learned in one sitting, it is easy to understand why people might find this option more desirable when compared to spacing (Baddeley et al., 1978; Son et al., 2009).

These findings could potentially be explained by encoding variability theory or deficient processing theory, two of the most prominent theoretical accounts of spacing (Mashhadi et al., 2018). Encoding variability theory suggests that the further apart study intervals are spaced, the more likely an individual is to associate learning with various contexts, thus creating a more powerful memory (Crowder, 1976; Maddox, 2016). This also aligns with encoding specificity principle, the idea that the environment in which information is learned can provide cues that prompt recall of that information (Tulving & Thompson, 1973; Parker et al., 2020). Due to the delay between study intervals, spaced-trained participants have the opportunity to associate greater context with learned material, thus potentially making it easier to retrieve said material under various circumstances. Moreover, an increase in the presence

of context-related cues increases the probability of a context match during the retest (Huff & Bodner, 2014). Deficient processing theory suggests that spaced-trained individuals are more attentive to subsequent presentations when compared to massed-trained individuals. Due to the involvement of working memory at each stage in learning, massed-trained individuals are more inclined to believe themselves familiar with the material and therefore are less attentive on consecutive presentations. In contrast, spaced-trained participants are inclined to feel less familiar with the material which leads to more vigilant encoding with each presentation (Cepeda et al., 2006). Callan & Schweighofer (2010) used fMRI to demonstrate the neural underpinnings of this theory: They found that participants demonstrate significant activity in the frontal operculum while utilising spaced schedules. There is no corresponding activity for massed-trained participants.

Furthermore, given that the face-name pairs task is thought to rely on the hippocampus (Smith et al., 2014), it is also possible that spaced advantages are due to the activation of this structure. For example, Li & Yang (2020) found that spaced-trained participants showed significantly greater hippocampal activity when recognising face-scene pairs compared to massed-trained participants. This activity was particularly pronounced at one-month intervals. Given also the involvement of the hippocampus in consolidating long-term memories (Scoville & Milner, 1957; Bercovitz et al., 2017; Delaney et al., 2018) and the importance of sleep in this process (Smolen et al., 2016), this could explain why distributed practice is so advantageous.

With respect to the second experiment, we found that the spacing effects were not as robust in the online condition compared to in-person testing. Although participants in the spaced condition could recall the names better overall, the effect was small. Furthermore, the better recall at longer intervals (1 month), reported in Experiment 1 and in the literature, was

not observed here. Where possible, the procedures used in the online experiment were copied exactly, however this was not always feasible given the change in medium and it is important to note that there were some key methodological differences between the experiments. In the in-person experiment, the Face-Name Pairs task was administered in video format. During the acquisition, participants had five seconds to study each face-name pair. Upon adapting the task for use via Qualtrics, the face-name pairs were displayed as a slideshow instead, using a timing function to ensure that each pair was on-screen for five seconds. It is possible that the timing on Qualtrics did not exactly match the timing of the video, as suggested by Plant (2016), however given that this experiment does not rely on millisecond timing (memory rather than reaction time), it is likely that any differences during acquisition were very minor, and we do not believe that this would impact the results in a major way. Of greater note were the differences during retention. As mentioned, in Experiment 1 faces were presented in video format during the retention phase - participants had five seconds in which to recall each associated name before the video would move on to present the next face. Participants were also required to say the name aloud while the researcher recorded their answers. Realistically, this was not possible through Qualtrics. In the online version, participants were required to type in the name. As this could be rather difficult to accomplish within five seconds, it was decided that participants would not be limited by time. Instead, the next face was presented only after the participant had typed in a name. Furthermore, in an attempt to avoid participants skipping through the task, the “force response” function was implemented. In other words, if participants did not know the name associated with a particular face, they had to provide a guess if they wished to proceed with the experiment. This is important as in the in-person set-up, participants were not required to guess. These differences would certainly explain why participants had a higher mean retention score in the online version compared to the in-person experiment, regardless of condition; more time to think about their answer and being forced to

provide a guess both lend themselves to better performance on the task. However, this does not explain why there is a reduced spacing effect.

The spacing effect has been well established in literature (Vlach et al., 2008; Benjamin & Tullis, 2010; Kapler, Weston, & Wiseheart, 2015; Delaney et al., 2018) and is evident in distanced, online learning too (Price Kerfoot et al., 2010; Fulton et al., 2013; Marzouk et al., 2016; Carvalho et al., 2021). This would suggest that spacing should occur even when the task is adapted for online administration. It remains unclear why spacing is so advantageous compared to massed learning, however there are a number of plausible theories, for example, encoding variability theory or deficient processing theory, among others (Smolen et al., 2016). It is possible that these behaviours did not occur or occurred in a reduced capacity during Experiment 2. For example, distractions or interruptions may have made it difficult for participants in the spaced condition to pay attention to stimuli on subsequent trials, resulting in a reduced capacity for encoding variability theory (Wong & Voyer, 2018). Similarly, the more relaxed nature of Experiment 2 may have resulted in participants feeling less engaged with the Face-Name Pairs task, thus leading to less vigilant encoding than deficient processing theory would assume. Given the difference in controlled environment between the two experiments, it is likely that participants responded differently to each. In the in-person experiment, the Face-Name Pairs task was conducted in a laboratory setting with a researcher present. In Experiment 2, participants were at liberty to complete the task in any setting and without the added pressure of a researcher recording their answers. As a result, it is possible that some participants performed better in an uncontrolled environment, while others may have been distracted or interrupted while partaking of the task. Such deviances may have led to an improvement in the performance of massed participants with a corresponding decline in the performance of spaced participants, thus eliminating the strong spacing effect in this sample. This is in line with Versteijlen et al. (2017), who suggest that engagement is a key component

of successful spacing when learning online. Moreover, some studies have indicated that spacing may occur online at longer time intervals only (Price Kerfoot et al., 2010). It is possible that our retention interval of 1 month was not long enough to allow for an obvious spacing effect in online participants.

Furthermore, although spacing is well established across many types of learning, it is worth mentioning that there is relatively limited research as to whether spacing is as effective when learning abstract concepts such as names. There are some studies to suggest that the spacing effect does occur when learning face-name associations (Carpenter & DeLosh, 2005; Hawley et al., 2008; Maddox et al., 2020). However, the sample size of these (and our own Experiment 1) are considerably smaller than that of the online experiment. It is possible that previous studies are underpowered, therefore leading to incorrectly rejecting the null hypothesis (Anderson et al., 2017). This could further explain why some online experiments fail to replicate lab-based research. As previously discussed, conducting experiments online can lead to a greater number and wider range of participants, which may in turn lead to a more powerful statistical analysis (Stevens, 1996; Langer & Beckman, 2005; Comley & Beaumont, 2011b) but the downside is the lack of experimental control.

In conclusion, the online experiment failed to robustly replicate the spacing effect observed at one month in the in-person experiment. This raises a number of questions about the potential for online research. Although there are a number of benefits, including larger, more generalisable datasets and ease of administration and use, there are also a number of potential pitfalls, particularly with regard to replicating established findings and adapting lab-based experiments.

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Declarations

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