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Spacing Effects for Face Recognition as a Function of Study-Phase Retrieval: Divided Attention and Age as Criteria for Automaticity

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Abstract

The spacing effect for the recognition of face-name pairs, faces and names was explored in Experiments 1a (focused attention) and 1b (divided attention). A lag 7 advantage was found across stimulus type under focused attention. When a tone monitoring task was introduce to divide attention, a robust spacing effect was found for faces, which was attenuated for face-name pairs but lost for names. Under focused attention involuntary processing for facial stimuli and voluntary processing for verbal (names) items accounted for the lag 7 advantage. When attention was divided, however, involuntary processing in the guise of study-phase retrieval remained unaffected explaining why a lag 7 advantage occurred for facial stimuli. Voluntary processing was prevented under divided attention which is why the lag 7 advantage for names was lost and attenuated for face-name pairs (the poor recognition performance for names was responsible for this). Another criterion which does not interfere with involuntary processing is age across the lifespan. In Experiment 2 a lag 7 advantage was explored for face recognition in a cohort of elderly adults. A robust spacing effect was found although face recognition performance decreased in comparison to younger adults tested in Experiment 1a. The contention that perceptual repetition priming is responsible for the lag 7 advantages incurred in face recognition was explored in Experiment 3a by changing the facial pose (from full-face to ¾ profiles or ¾ profiles to full-face) across presentations during the learning phase. At test faces were either full-face or ¾ profile poses. The lag 7 advantage was lost regardless of pose presented at test. It was assumed that participants were unable to 'recognise' the second presentation due to a structural change and therefore unable to process target repetitions. In Experiment 3b a forced repetition detection task was introduced during the learning phase. Despite detection, the lag 7 advantage remained lost. High detection scorers did not perform any better than low detection scorers. The division of low and high detection scorers showed that the spacing effect was independent of detection and recognition performance. Moreover, in the case of recognition for faces, the spacing effect relies on perceptual repetition priming. When the structural content of the face is the same across presentations, study-phase retrieval operates and produces a robust lag 7 advantage. In the case of the names, deficient-processing best accounts for the spacing effects seen because when voluntary processing is prevented, the lag 7 advantage is lost.

Keywords: Spacing effect; Lag effect; Distributed and massed learning; Face-recognition; Focused and divided attention; Voluntary and involuntary processing; Perceptual repetition priming

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Abbrevations: ANOVA: Analysis of Variance; TP: True Positive Hit; FP: False Positive Error

Introduction

The repetition of information is a successful approach to improving recall and recognition of visual [1,2] and verbal [2,3] stimuli. This increased frequency of learning or contact with a stimulus induces improved memory retention. This is not an outstanding finding as it is common knowledge that 'practice makes perfect'. The benefit of repetition in learning, however, is facilitated by the temporal distribution of the second presentation of the stimulus item, such that a longer interval between presentations induces further increases in retention. In other words, distributed repetition of stimuli induces superior learning and retention than massed repetition. Melton [4] introduced the spacing paradigm as an experimental methodology that enabled researchers to study the benefits of massed repetition over no repetition and distributed repetition over massed repetition. Target items were repeated immediately after the first presentation (i.e. massed or lag 0) or spaced throughout the sequence (i.e. inter-serial or distributed (lag 'n')). Melton presented the target item twice but introduced a lag 1 where a different item (i.e. filler) was interpolated between the target presentations. Learning and retention increased at lag 1 over lag 0. Moreover, further improvements to learning and retention occurred as the number of filler items interpolated between target repetitions increased. Hence, a monotonic increase in performance occurred with increasing lag. Collectively spacing effects include a:

i. Repetition effect – enhanced performance over a single presentation
ii. Spacing effect – enhanced performance by interpolating one item between target presentations
iii. Lag effect – enhanced performance beyond the spacing effect as interpolations between first and second target presentations increment

Studies using the classic spacing paradigm have demonstrated the robustness of repetition and more specifically distributed learning. Spacing effects have been found using non-human animals [5] and humans of different ages: human infants [6]; children [3,7-9] and elderly adults [10,11]. Spacing effects are robust and occur using different stimulus types such as mastering the rotary pursuit task [12]. Many researchers have explored spacing effects using verbal stimuli: basic memory tasks using words [13,14] discriminating a correct word of a pair [15] information from textbooks [16] recall for English-Spanish word pairs [17] learning new vocabulary [18] retention of propositions written in a paragraph [19] self-governed lag values in paired associate learning [20] estimation accuracy of frequency judgements [21] and multiplication facts and spelling lists [7]. Other researchers have used non-verbal material: picture scenes [1] other race faces [22] unfamiliar faces [2] and selection of culprits in sequential line-ups [23]. A combination of both verbal and non-verbal material has also been used: verbal and non-verbal meaningful and meaningless stimuli [24-26]. Intentional and incidental learning formats have also been adopted to explore the retention of spacing effects: incidental learning [27,28] and estimation of word frequency judgement using intentional and incidental formats [29]. Some researchers have focused on free recall [30] recognition [2] and the effects of delayed retention testing [31] and contextual enrichment [32].

There have been many theoretical accounts aimed at explaining the distributed learning advantage but the focus of this paper is to consider Greene's two-process account of deficient-processing and study-phase retrieval. In the case of study-phase retrieval, processing is considered to be involuntary – without conscious intention. Greene [33] argued that cued memory tasks rely on intentional rehearsal. Moreover, due to the familiarity of the second presentation of the item under massed repetition less rehearsal occurs. In contrast, under distributed repetition, the second presentation is less likely to be recognised as a repetition and therefore undergoes more rehearsal. The important manipulation in the spacing paradigm, according to Greene, is intentionality.

Intentionality should influence the spacing effect under conditions of cued-memory but not free recall. Automatic non-intentional processes inherent in study-phase retrieval should remain unimpaired by intentionality. This implies that the introduction of a distractor should not interfere with automatic study-phase retrieval processing thereby preserving a spacing effect in free recall. As the introduction of a distractor task should impair any rehearsal activity occurring under distributed repetition for cued-recall, the extent of rehearsal for the second item presentation is predicted to be similar across massed and distributed conditions. Therefore the advantage of distributed repetition is attenuated or lost. Greene also claimed that a spacing effect is lost when rehearsal is prevented under incidental learning.

Experiments by Russo et al. [2], however, have demonstrated that spacing effects can be obtained under focused and divided attention using incidental learning by adopting a 'levels of processing' approach. They found that while overall performance was affected by divided attention, the spacing effect for word recognition memory is preserved. Furthermore, Russo et al. [2] failed to obtain a spacing effect for word recognition memory under divided attention, which was interpreted as preventing semantic processing. Under focused attention a spacing effect for word recognition memory was found which meant that semantic processing was unimpaired. Under intentional (focused) but divided attention, reduced semantic processing in cued-memory is central to the loss of a spacing effect. These findings collectively not only imply that intentional rehearsal fails as a key explanation for spacing effects in cued-memory tasks as purported by Greene, but the importance of semantic processing and not perceptual repetition priming is operating in cued-memory. Hence, the inclusion of unfamiliar facial material in further experiments by Russo et al. [2] as a means to differentiating the mechanisms involved in spacing effects for non-verbal stimuli. They found a spacing effect for the recognition of faces in both focused and divided attention. This suggests that semantic priming is not responsible for the spacing effect under conditions of face recognition.

Russo et al. [2] findings allude to perceptual repetition priming for the recognition of unfamiliar faces. Moreover, the spacing effect under these conditions provides evidence of study-phase retrieval. This means that the processing of faces using the spacing paradigm is an involuntary process. Hasher & Zack's [34] claimed that there are overlapping features between involuntary and automatic processing, which make them similar. Some of the criteria underlying an involuntary process can also be applied to an automatic process such as impunity towards divided attention effects and age across the lifespan. As found by Russo et al. [2] divided attention using unfamiliar faces does not attenuate the spacing effect. Explicit (or voluntary processing) and implicit (or involuntary processing) memory are important in understanding study-phase retrieval.

An explicit task involves conceptually driven processes in contrast to the data driven processes involved in implicit tasks [35]. The evidence for involuntary processing in implicit memory is robust [36-39]. Superior face recognition in distributed repetition found by Russo et al. [2] despite divided attention, adds support to the contention that spacing effects derive from implicit memory thereby involving data driven processing beyond conscious control. They did, however, offer a multi-process account for spacing effects *per se*. Given that the stimulus material used, the experimental procedure manipulated and the type of participants considered, collectively and independently impacted on the processes underlying the distributed learning advantage, a multi-process account best explained their findings.

Another criterion for an automatic process purported by Hasher & Zack's [34] was age. They claimed that an automatic process should be impervious to differences of age. Processes that are consciously mediated, however, are likely to undergo impairment. Hence, older individuals are more likely to show impaired performance on explicit memory tasks such as intentionally remembering words. Light et al. [40] for example, found impaired word recognition memory (explicit memory) but intact fragment completion (implicit memory) in young and elderly participants. Despite word recognition performance for older participants being impaired in comparison to their younger counterparts, fragment completion remained the same across the two age cohorts. Rea & Madigliani [41] gathered evidence to show that the spacing effect does not develop with age, but rather relies on involuntary processes. The spacing effect was found in children aged four to nine years. They were shown words and pictures presented at lags 0, 1 and 3. According to Hasher & Zack's [34] age does not interfere with the spacing effect which is indicative of an involuntary process driving it. Moreover, by the age of four, children are less likely to have developed effective memory strategies for learning information. Memory strategies are effortful such as rehearsal or effective encoding, and are more likely to be adopted by older children.

Aims and Hypotheses

The aim of Experiments 1a and 1b was to investigate the effects of focused and divided attention on the recognition of face-name pairs respectively. For the second experiment the aim was to investigate whether a spacing effect can be obtained in an elderly cohort using faces. The aim of Experiments 3a and 3b was to investigate whether spacing effects for face recognition rely on perceptual repetition priming.

The following hypotheses were made:

i. Hypothesis 1 (H_1): A spacing effect for the recognition of unfamiliar face-name pairs, faces and names will occur under focused attention. A spacing effect for the recognition of unfamiliar faces will occur under divided attention but attenuated for face-name pairs and lost for names.

ii. Hypothesis 2 (H_2): A spacing effect for the recognition of unfamiliar faces will be found among an elderly cohort.

iii. Hypothesis 3 (H_3): A spacing effect for the recognition of unfamiliar faces will be lost for face-pose transformation during the learning phase.

iv. Hypothesis 4 (H_4): A spacing effect for the recognition of unfamiliar faces is independent of repetition detection of a different facial pose for the second presentation during the learning phase.

Generic Methodology

The following spacing experiments were devised such that there was a learning and test phase. During the learning phase there were two independent repetition conditions: massed (or lag 0) and distributed (or lag 7). In the learning phase 20 target unfamiliar faces were repeated (40) with 20 filler items used to make up the number of faces necessary for lag sequences (total of 60 faces). Sequences began and ended with two or three filler items to allow for primacy and recency effects. A five minute retention period occurred before the test phase commenced. In the test phase 25 distractor faces were shown in addition to the 20 target faces seen during the learning phase and were randomly mixed. The same faces were used across lag conditions, so that the problem of any significant effect between lag groups arising will be less likely due to the nature of the inherent differences between faces used. Unfamiliar female faces were prepared in vignette style to exclude cues that could be used to increase their memorability such as clothing, jewellery, eyeglasses and distinctive hair additions. Faces were photographed in black and white against a white back drop to exclude contextual cues.

Ethical Issues

This study was passed by the Experimental Psychology Ethics Committee of the University of Sussex. Informed consent was provided by each individual tested.

Experiment 1a

Introduction: Spacing effects for the recognition of unfamiliar faces is a robust finding, providing evidence of Greene's study-phase retrieval. This finding can equally be accounted for by Hasher & Zack's [34] automatic-effortful processing divide. Two of their six criteria for an automatic process considered here, are simultaneous processing demands (i.e. divided attention; Experiment 1b) and age across the lifespan (Experiment 2). Rehearsal of facial stimuli implies that learning is intentional but previous research suggests the processing underlying face recognition is not dependent on voluntary mechanisms. Semantic processing occurs when verbal stimuli such as words are to be learned which suggests intentionality. In Experiment 1a, the spacing effect was investigated by pairing a face with its corresponding surname. It is assumed that the learning of names will require a different processing mechanism to the learning of faces. Therefore by using face-name pairings, the underlying processing for the faces and surnames should be different.

By adopting a paired association study stimulus, it should be possible to differentiate the recognition performance of faces and names. A spacing effect for faces, names and face-name pairs should occur, but be reliant on different processing pathways. Carpenter & DeLosh [42] accounted for their spacing effect for unfamiliar face-name pairs using the multifaceted account suggested by Russo et al. [2] Their findings support the view that deficient semantic processing does not explain spacing effects across all situations. Instead deficient semantic processing explains spacing effects obtained using familiar and meaningful stimuli as is the case for words. Perceptual repetition priming alternatively, underlies spacing effects obtained with unfamiliar stimuli such as face-name pairs.

Participants: Forty male and female students based at the University of Sussex, were randomly allocated to one of two lag conditions – hence 20 served in lag 0 and 20 in lag 7.

Materials and Design: During the learning phase 60 faces were paired with a random surname. An unrelated design was adopted such that participants were presented with either a lag 0 or lag 7 sequence. Full-face poses matched with their corresponding surname (face-name pair) were presented together on the same slide for eight seconds during the learning phase. Target faces were repeated with their matched surname. Filler faces with their matching surname were distributed among the learning phase according to lag sequences. At test 20 target face-name pairs were distributed among 25 distractor face-name pairs. At test ten of the target faces were correctly matched with the original surname presented during the learning phase. The other ten target faces were matched with new different names. In addition to this, of the 25 distractor faces, ten were paired with ten of the original target surnames and 15 with their distractor names (all new names not seen previously).

Procedure: Instructions were given to participants to remember each face-name pair as they would be tested on completion of the sequence. At test they were provided with a response sheet. This consisted of two separate columns: faces and names. A forced-choice recognition response of 'yes' or 'no' was allowed. Responses involved two questions which relied on their initial response to the faces shown at test. If they indicated 'yes' to the current face shown, then they had to consider whether the surname shown with the face comprises the correct face-name pair. This was answered in the names column. If they indicated 'no' to the current face shown, then they had to consider whether they had previously seen the corresponding name. Participants responded accordingly in the names column.

Results and Discussion: For each participant, three discrete scores were calculated: correct target faces; correct target names and correct target face-name pairs. A d-prime (d′) score was calculated by converting the true positive hit (TP) and false positive error (FP) ratios. Mean d-prime scores were then compared using a 2x3 ANOVA (Table 1).

Stimulus type	Lag 0			Lag 7		
	TP	FP	d′	TP	FP	d′
Face-name pairs	12.70	1.50	2.14	15.40	1.15	2.69
Faces	15.90	4.25	2.14	18.10	2.75	2.84
Names	14.35	4.00	1.91	15.60	2.90	2.40

Table 1: Mean TP, FP and d′ scores for recognition performance in lags 0 and 7.

ANOVA yielded a significant difference for lag ($F(1,38)=6.15$, $p<0.05$); a non-significant difference for stimulus type ($F(2,76)=2.71$, $p>0.05$) and a non-significant interaction across lag and stimulus ($F(2,76)=0.25$, $p>0.05$). A spacing effect was found demonstrating the lag 7 advantage for all stimulus type. The recognition performance across face-name pairs, faces and names failed to significantly differ. This is an expected finding given the historical background of spacing effect research. It is suspected that face processing relies on study-phase retrieval (involuntary ~implicit) processing and names on semantic processing (voluntary ~ explicit) processing which both operate favourably under conditions of focused attention.

Experiment 1b

Introduction: In Experiment 1a a spacing effect was found for all stimulus type (face-name pairs, faces and names), although they did not differ significantly in terms of recognition performance. Spacing effects, regardless of stimulus type, is expected under conditions of focused attention but in Experiment 1b the effects of divided attention is expected to have a differential effect on involuntary and voluntary processing. If spacing effects in the recognition of unfamiliar faces are derived from involuntary processing, as is stated in Greene's [33] study-phase retrieval, then the addition of a simultaneously performed task should not interfere with this mechanism. Hence, a spacing effect should remain intact. This also follows from Hasher & Zack's [34] automatic-effortful processing divide, where names require voluntary processing using different rehearsal and encoding strategies and faces undergo involuntary processing beyond conscious direction. In the case of recognition for names, there is a degree of semantic intentional processing. A simultaneously performed task, dividing attention, will limit the extent of semantic rehearsal (or effortful processing) available. It is predicted that the spacing effect for name recognition in Experiment 1a would be either attenuated or lost. In the case of face recognition, the spacing effect will remain intact but attenuated for face-name pairs.

Participants: Forty male and female students based at the University of Sussex, were randomly allocated to one of two lag conditions – hence 20 served in lag 0 and 20 in lag 7.

Materials and Design: The materials and design was the same as Experiment 1a with the exception of a tone detection task which varied according to three levels of tone (low, medium and high). These tones were from a randomised sequence that had been synthesised by a computer. These tones were presented via headphones and heard randomly during stimulus presentation. All participants heard the standardised sequence of tones during the learning phase. Participants were instructed to learn the face-name pairs while simultaneously detecting the correct level of the tones. The importance of detecting the tones correctly was stressed in order to ensure divided attention.

Results and Discussion: Results for face-name pairs, faces and names were calculated in the same way as Experiment 1a (Table 2). Additionally tone detection was analysed using the number correct out of the total number presented during the learning phase. The possible number correct was 73 but to ensure that divided attention had occurred a 5% cut off point was introduced. This was calculated at 3.65 (rounded up to 4). If participants exceeded this their data was excluded and replaced with a new participant (Table 3).

Stimulus type	Lag 0			Lag 7		
	TP	FP	d′	TP	FP	d′
Face-name pairs	10.35	1.95	1.63	13.25	1.75	2.11
Faces	13.95	6.30	1.36	16.65	4.15	2.45
Names	14.25	6.40	1.44	14.50	5.25	1.65

Table 2: Mean TP, FP and d′ scores for recognition performance in lags 0 and 7.

Lag 0		Lag 7	
Correct	Error	Correct	Error
70.25	2.75	70.15	2.85

Table 3: Mean number of tones correctly identified and the number incorrect across lags 0 and 7.

ANOVA yielded a significant difference for lag ($F(1,38)=7.04$, $p<0.05$); a significant difference for stimulus type ($F(2,76)=4.19$, $p<0.05$) and a significant interaction across lag and stimulus ($F(2,76)=5.58$, $p<0.05$). The location of difference was examined more closely and found to be a consequence of increased face recognition performance at lag 7. This was confirmed using the unrelated t-test to compare lags 0 and 7 for faces ($t=4.109$, $df=38$, $p<0.001$). Difference in lag for the face-name pairs and names failed to reach significance ($t=1.684$, $df=38$, $p>0.05$ and $t=0.777$, $df=38$, $p>0.05$ respectively). The point of interaction can be seen in Figure 1. When results from Experiments 1a and 1b are combined, it is clear that divided attention reduces recognition performance *per se* across all stimulus type but a spacing effect for faces is preserved, attenuated for face-name pairs and lost for names (Figure 2).

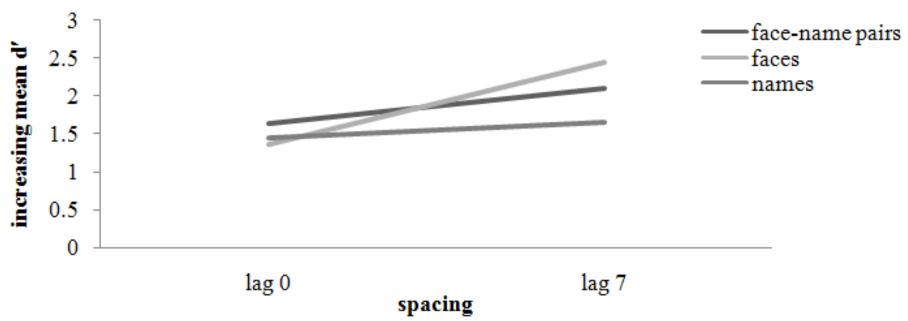

Figure 1: The interaction between mean d′ recognition scores across lag and stimulus type under divided attention.

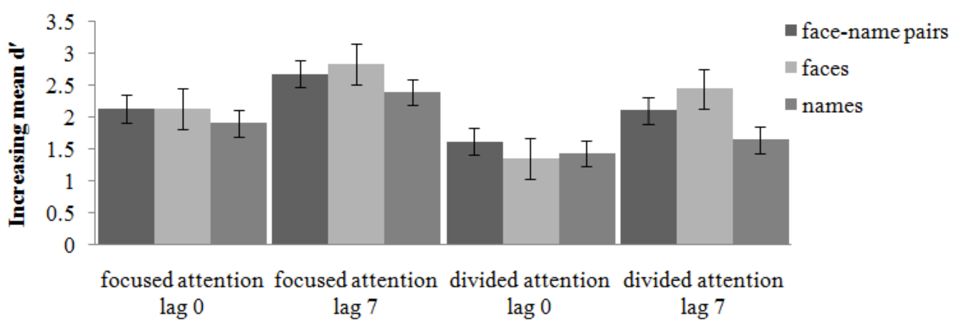

Figure 2: Recognition mean d′ scores across lag and stimulus type as a function of focused and divided attention.

It is difficult to assume the spacing effect is totally driven by automatic processing as the advantage of a lag 7 format for face-name pairs, faces and names is differentially affected by the introduction of a divided attention task such as monitoring tones. The lag 7 advantage for faces remains intact under divided attention albeit recognition performance is reduced in comparison to the focus attention condition. The lag 7 advantage for face-name pairs is attenuated under divided attention which is a consequence of poor name recognition performance. This relates to the scoring of face-name pairs where both had to be correctly matched. It was therefore predicted that face-name pairing recognition would lie between face and name stimuli – this is the case (Figure 2). It can therefore be concluded that the underlying mechanism driving the spacing effect for faces is automatic. In the case of name recognition, effortful processing is required. Under divided attention, such effortful processing is prevented. The spacing effect therefore is intricately related to the nature of the stimulus and the level of processing capacity used.

Applying Greene's [33] two process model, the findings allude to a study-phase retrieval explanation for the recognition of faces and a deficient-processing account for spacing effects observed for names. Hence, the second presentation of the stimulus receives less processing under lag 0 sequences than observed under lag 7 ones *per se*. This was particularly noticeable under divided attention, for name recognition where the second presentation for lag 7 failed to receive as much voluntary processing. For faces, however, the amount of involuntary processing for the second presentation increased significantly, despite divided attention. H_1 is therefore supported.
H_2 was explored in Experiment 2 using an elderly adult cohort of participants. In this study, the spacing effect was investigated using faces only.

Experiment 2

Introduction: According to Hasher & Zacks [34] involuntary processing is unaffected by age across the lifespan. They considered the effects of age on frequency judgements. Objects were repeated one, two, three or four times to children varying in age. No difference in performance for this task was found despite younger children being unaware of imagery and rehearsal strategies that could aid performance. Delaney et al. [43] suggest that rehearsal or voluntary processing fail to provide a comprehensive account of spacing effects observed across the lifespan. Young children, for example, they argue have not yet developed the necessary rehearsal and encoding skills underlying effortful processing. Spacing effects in children using recognition are robust [44,45] as it is for free recall [46]. Older adults also show spacing effects [10,47]. Benjamin & Craik [11] found a distributed learning advantage over massed presentations in both young and old adults. In Experiment 2, the spacing effect for the recognition of unfamiliar faces was explored using an elderly cohort.

Participants: Thirty-six elderly people ranging between the ages of 65 and 80 based at a Residential Home were randomly allocated to one of two lag conditions – hence 18 served in lag 0 and 18 in lag 7.

Materials and Design: The same faces and design were adopted as Experiment 1a. The faces, however, were presented without the surname. Participants were required to respond by indicating on the response sheet whether the face shown had been seen during the learning phase.

Results and Discussion: For each participant, a score was calculated: correct target faces. A d′ score was calculated by converting the true positive hit (TP) and false positive error (FP) ratios (Table 4).

	TP	FP	d′
Lag 0	14.40	7.70	1.16
Lag 7	18.20	7.20	2.07

Table 4: Mean TP, FP and d′ scores for recognition of faces in lags 0 and 7.

Mean d′ scores were compared across lags 0 and 7 using an unrelated t-test. A significant lag effect was found ($t=4.356$, $df=34$, $p<0.001$). This finding supports Hasher & Zacks' [34] assumption that the spacing effect for face recognition is impervious to age difference. Moreover, this provides evidence for automaticity in the processing of faces. This also supports Greene [33] study-phase retrieval. Hence, involuntary processing underlies the spacing effect when the measure of face recognition is adopted.

The findings obtained here support H_2. There appears to be a robust spacing effect for faces but are there any circumstances where the lag 7 advantage is attenuated or lost completely? Thus far, the second presentation of faces has been the same as the first. In Experiments 3a and 3b the spacing effect was explored by introducing the manipulation of facial pose transformation during the learning phase.

Experiment 3a

Introduction: In Experiments 1 and 2 the facial pose adopted was full-face and this was the case for the first and second presentations across lag. A spacing effect for faces occurs when the surface structure of the face presentations remain constant during the learning phase. An interesting question is whether the distributed presentation advantage is preserved when facial pose is transformed during learning. In this study, participants will be tested for face recognition but also implicitly for the recognition of a facial pose seen during the learning phase. It is assumed that the increased face recognition performance gained in distributed learning occurs as a function of study-phase retrieval processing that is driven by involuntary processes. Russo et al. [2] suggested that spacing effects for face recognition might be dependent on perceptual repetition priming, in which case the same stimulus item occurs for both presentations. If this is the case, then by introducing a pose transformation during the learning phase the spacing effect might be attenuated or lost.

Participants: Forty-eight male and female students based at the University of Sussex were randomly allocated to one of two lag conditions – hence 24 served in lag 0 and 24 in lag 7.

Materials and Design: The same models were previously photographed using two linked cameras synchronised to take a full-face and ¾ profile shot of the face in vignette style. Both full-face and ¾ profile poses were presented during the learning phase, counterbalanced such that for half of the participants a full-face pose appeared first and a ¾ profile pose second and *vice versa* across both lags. Equal numbers of both poses appeared for filler items. Each of the two lag conditions were divided forming two sub-groups. There were four sub-groups, each consisting of 12 participants. A sub-group from each lag were presented with a sequence of full-face or ¾ profiles at test. The target faces were randomly distributed among the 25 distractor faces (which were also full-face or ¾ profiles depending on the sub-group condition). On the response sheet, participants indicated whether they had seen the face before regardless of pose.

Results and Discussion: For each participant, a score was calculated: correct target faces. A d′ score was calculated by converting the true positive hit (TP) and false positive error (FP) ratios (Table 5).

	Lag 0			Lag 7			
Pose at test	TP	FP	d′	TP	FP	d′	Order of pose at learning
Full-face	16.0	5.0	1.79	16.8	4.3	2.07	ff - ¾
	15.2	3.8	1.77	16.3	3.2	2.25	¾ - ff
			Mean=1.78			Mean=2.16	
¾ profile	15.0	4.2	2.02	18.0	6.0	2.22	ff - ¾
	17.3	4.0	2.17	18.0	5.5	2.12	¾ - ff
			Mean=2.09			Mean=2.18	

Table 5: Mean TP, FP and d′ scores for recognition of faces in lags 0 and 7as a function of pose and order of pose at learning and test.

A 2x2x2 ANOVA was performed on these data. No significant effects of lag ($F(1,40)=1.62$, $p>0.05$); pose at test ($F(1,40)=0.86$, $p>0.05$) and order of pose presentation during learning ($F(1,40)=0.11$, $p>0.05$) were found. As the figures in Table 5 indicated a mean d′ score difference between lags 0 and 7 for full-face poses at test, it was decided to perform a 2x2 ANOVA. This marginally failed to reach significance ($F(1,20)=3.79$, $p>0.05$. Failure to obtain a significant lag effect for full-face or ¾ profiles shown at test suggests that pose transformation during the learning phase disrupts the mechanisms underlying the spacing effect on recognition. The spacing effect appears to rely upon identical repetitions during the learning phase which supports the assumption that face recognition relies on perceptual repetition priming [2] H_3 is therefore supported.

Experiment 3b

Introduction: It was demonstrated in Experiment 3a that pose transformation during the learning phase eliminates the lag 7 advantage for face recognition. One possible explanation for this could be a decreased awareness of the relatedness of the first and second presentations. The introduction of a repetition detection task would increase conscious awareness of the second repetition thereby inducing further processing - increasing the probability of study-driven encoding. This is in line with Greene's deficient-processing account of spacing effects. It can be argued that a repetition recognised during the learning phase should induce a potentiating effect which ultimately increases the chance of being recognised at test. In Experiment 3a, participants might have failed to detect the transformed pose of a face previously presented. If participants are forced to detect repetitions, the spacing effect might be restored. This induced detection is predicted to increase awareness of the second presentation and restore the spacing effect. If this is the case, then support for a voluntary processing account of the spacing effect can be concluded. Alternatively, if the spacing effect is not restored, then involuntary processes underlie face recognition that operate best when stimuli remain constant.

Participants: Eighty-four male and female students based at the University of Sussex were randomly allocated to one of two lag conditions. The two lag conditions were divided into two sub-groups such that there were 24, 24, 18 and 18 participants in each sub-group.

Materials and Design: The materials and design was the same as Experiment 3a. In this study, however, there was an additional manipulation during the learning phase of repetition detection. Participants informed the experimenter of any repetitions which were recorded onto a response sheet. Participants were informed of a recognition test on completion of the learning phase – this was to introduce an incidental learning paradigm. At test a response sheet was provided as previous experiments.

Results and Discussion: For each participant, a repetition detection d′ score was calculated using TP and FP scores. The highest TP score was 20 and 39 for FPs (this is because the first face shown cannot be regarded as a repetition) (Table 6). For each participant, a recognition score was calculated: correct target faces. A d′ score was calculated by converting the true positive hit (TP) and false positive error (FP) ratios (Table 7).

	Lag 0			**Lag 7**		
Pose at test	TP	FP	d′	TP	FP	d′
Full-face	16.96	2.87	2.80	9.71	2.25	1.61
¾ profile	17.00	3.83	2.73	12.28	4.94	1.54

Table 6: Mean TP, FP and d′ scores for repetition detection at lags 0 and 7.

A 2x2 ANOVA yielded a significant result for lag ($F(1,80)=61.55$, $p<0.001$) and a non-significant effect of pose at test ($F(1,80)=0.23$, $p>0.05$).

	Lag 0			**Lag 7**		
Pose at test	TP	FP	d′	TP	FP	d′
Full-face	15.50	4.16	1.99	15.38	2.42	2.20
¾ profile	16.20	5.10	1.91	17.00	6.20	1.97

Table 7: Mean TP, FP and d′ scores for recognition at lags 0 and 7.

A 2x2 ANOVA yielded no significant effect of lag ($F(1,80)=1.01$, $p>0.05$) or pose at test ($F(1,80)=1.44$, $p>0.05$).

A 2x2x2 ANOVA was performed by combining the results of Experiments 3a and 3b. Non-significant effects of repetition detection ($F(1,124)=0.20$, $p>0.05$) and pose at test ($F1,124)=0.00$, $p>0.05$) were found. Lag was significant ($F(1,124)=3.97$, $p<0.05$) where a marginal lag 7 advantage for recognition was found. This significant result was derived as a consequence of the slight differences of performance for full-face poses at test across lags 0 and 7 in Experiments 3a and 3b. Hence, these small differences combined to produce marginal lag 7 effects. Repetition detection did not significantly influence recognition performance *per se*. A median-split analysis was used to divide repetition detection data according to low and high scorers within the lag manipulation (Table 8 & Figure 3). The division between low and high scorers was successfully mutually exclusive using the median-split.

	Pose at Test			
	Full-face		**¾ profile**	
	LD	HD	LD	HD
Lag 0	2.11	3.49	1.94	3.52
Lag 7	1.21	2.02	1.12	2.24

Table 8: Mean d′ repetition detection scores for low (LD) and high (HD) scorers across lag.

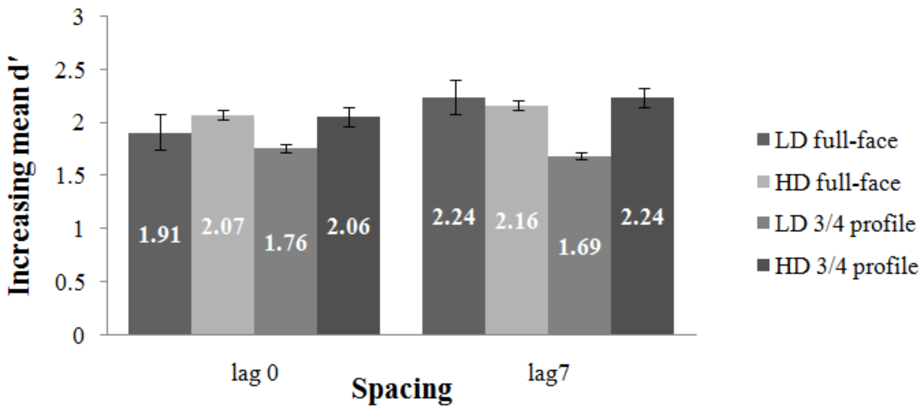

Figure 3: Mean d′ recognition scores for low (LD) and high (HD) repetition detection scorers across lag.

No significant lag effects for low repetition detection scorers were found for full-face and ¾ profiles at test using unrelated t-tests (t=1.321, df=22, p>0.05 and t=0.235, df=16, p>0.05 respectively). There were no significant lag effects for high repetition detection scorers for full-face and ¾ profiles at test (t=0.299, df=22, p>0.05 and t=0.557, df=16, p>0.05 respectively). These findings show that a spacing effect is unaffected by high or low repetition detection rates thus supporting H_4. Low and high repetition detection scores were further analysed using Pearson Product Moment Correlation. It was assumed that low repetition detection would lead to low recognition performance and high repetition detection to high recognition performance. This comparison yielded a non-significant positive correlation between detection and recognition measures (r=0.177, df=83, p>0.05). This finding suggests that the two measures are independent of each other.

General Discussion and Conclusion

The findings from Experiment 1a demonstrated a lag 7 advantage for the recognition of three different types of stimuli: face-name pairs, faces and names. Moreover, the recognition performance level was consistent across these stimuli. This is in keeping with previous research findings. Spacing effects for verbal and non-verbal stimuli are expected although the underlying processing mechanisms might be different. To explore the influence of divided attention on the robustness of a spacing effect for face-name pair, face and name recognition performance, a tone monitoring task was introduced. In Experiment 1b, it was assumed that by dividing attention in this way, the voluntary processing mechanism underlying spacing effects for verbal material, in this case surnames, would be attenuated hence, eliminating any lag 7 advantage. In the case of non-verbal stimuli such as unfamiliar faces, study-phase retrieval processes, that are involuntary driven, would preserve the spacing effect. Findings from Experiments 1a and 1b support these assumptions and confirmed Hypothesis 1.

The addition of a tone monitoring task prevents the rehearsal of names and supports Hasher & Zacks' [34] automatic-effortful processing divide. Nevertheless, an attenuated lag 7 advantage remains for the recognition of face-name pairs which alludes to the mechanisms underlying the spacing effect as not entirely involuntary driven. The spacing effect, it would seem, is a complex phenomenon that depends on the type of stimulus material used and the amount of processing capacity available. Using Greene's [33] two process models, study-phase retrieval accounts for the spacing effect obtained for the recognition of unfamiliar faces. Deficient-processing, alternatively accounts for spacing effects occurring for the recognition of names in focused attention. Hence, the second presentation in lag 0 conditions fails to receive further processing due to its immediate proximity to the first presentation of the stimulus item. In lag 7 conditions, the second presentation receives further processing. In divided attention, however, voluntary processing for names in lags 0 and 7 is reduced considerably. This is not the case for faces. An attenuated spacing effect for face-name pairs in divided attention is a consequence of the poor recognition performance for the names.

As the spacing effect is robust for the recognition of faces under focused and divided attention, a second criterion of Hasher & Zack's [34] that an involuntary driven mechanism is impervious to variations in age was investigated. As there have been many studies investigating spacing effects in children, it was decided to consider the other end of the age spectrum: an elderly adult cohort. The findings of Experiment 2 demonstrate that individuals ranging between 65 and 80 years, despite having a lower recognition performance score for facial stimuli (as compared with Experiment 1a), still show a robust lag 7 advantage seen in younger adults. This finding supports Greene's study-phase retrieval as the involuntary process mechanism underlying spacing effects for face recognition. As Experiments 1a, 1b and 2 provide strong evidence for an automated processing mechanism underlying spacing effects for face recognition, the next stage was to explore whether this relies upon both presentations being structurally the same. In Experiment 3a this assumption was explored by manipulating pose transformation across presentations one and two during the learning phase.

Russo et al. [2] introduced perceptual repetition priming as a possible explanation of spacing effects in face recognition. By changing the pose from full-face to ¾ profile or *vice versa* during the learning phase and at test showing either a full-face or ¾ profile, the spacing effect was lost (supporting Hypothesis 3). This finding added credence to the argument that perceptual repetition priming is at the heart of spacing effects for face recognition. Moreover, the change in facial pose across presentations during the learning phase disrupts the involuntary mechanisms driving the spacing effect in face recognition. It is possible that pose transformation makes it difficult for participants to 'recognise' a repetition during learning such that any awareness of the relatedness between two presentations is considerably decreased. For this reason, a repetition detection task was introduced to Experiment 3b during the learning phase as an added dependent variable to increase conscious awareness of the second repetition. This forced repetition detection task did not help to restore the spacing effect. Even when repetition detection scores were divided into low and high detectors, there was no relationship between recognition performance and a spacing effect. This suggests that involuntary processes underlying the spacing effect for face recognition operate most effectively when the structural content of the face remains consistent (supporting Hypothesis 4).

What can we collectively conclude from these findings? It is clear that spacing effects occur across verbal and non-verbal stimuli but have different underlying processing mechanisms. These processing mechanisms can be teased out under conditions of divided attention: where spacing effects for face recognition remain intact but attenuated for face-name pair recognition and lost for name recognition. Hence, involuntary processing such as that stipulated in Greene's [33] study-phase retrieval occur for face recognition and voluntary (effortful) processing or deficient processing in the case of name recognition. Involuntary processing underlying the spacing effect for face recognition is further supported by considering an elderly adult cohort. Despite decreased face recognition performance, the spacing effect remains robust. Altering the structural content of the second presentation from the first during learning eliminates the spacing effect for face recognition. This supports Russo et al. [2] assumption that perceptual repetition priming in face recognition plays a key role in the spacing effect. Despite a forced repetition task during learning as a means of increasing awareness of the relatedness of first and second presentations, the spacing effect was not restored. The spacing effect for face recognition therefore is a robust phenomenon as long as the structural content of the face remains the same across presentations; once this is transformed, the involuntary processes fail to operate optimally and the lag 7 advantage is lost.

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