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The speed of recognition of personally familiar faces

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Abstract. Despite the generally accepted notion that humans are very good and fast at recognising familiar individuals from their faces, the actual speed with which this fundamental brain function can be achieved remains largely unknown. Here, two groups of participants were required to respond by finger-lift when presented with either a photograph of a personally familiar face (classmate), or an unfamiliar one. This speeded manual go/no-go categorisation task revealed that personally familiar faces could be categorised as early as 380 ms after presentation, about 80 ms faster than unfamiliar faces. When response times were averaged across all 8 stimulus presentations, we found that minimum RTs for both familiar and unfamiliar face decisions were substantially lower (310 ms and 370 ms). Analyses confirmed that stimulus repetition enhanced the speed with which faces were categorised, irrespective of familiarity, and that repetition did not affect the observed benefit in RTS for familiar over unfamiliar faces. These data, representing the elapsed time from stimulus onset to motor output, put constraints on the time course of familiar face recognition in the human brain, which can be tracked more precisely by high temporal resolution electrophysiological measures.

1 Introduction

It is generally stated that recognising a familiar face is efficient and fast, even given dramatic changes of viewing conditions (Bruce 1982; Hill et al 1997; Burton et al 1999; Tong and Nakayama 1999; Bruce et al 2001; Sinha et al 2006). The observation of superior performance for familiar, as compared to unfamiliar, face categorisation (eg Herzmann et al 2004, experiment 1; Baird and Burton 2008) suggests that familiarity is associated with a reliable processing benefit, a notion which receives indirect corroboration from reports of differential priming effects for unfamiliar and familiar faces (eg Ellis et al 1990).

However, the actual time required to categorise faces as familiar and unfamiliar remains to be determined, as the response times (RTs) reported across studies are extremely variable. To our knowledge, the shortest RTs for familiar face decisions have been reported by Anaki et al (2007) and Kampf et al (2002), who found average RTs of 411 ms and 431 ms for categorisation of upright famous faces. Caharel et al (2005) reported that personally familiar faces were recognised within 491 ms on average; Valentine and Bruce (1986) found that RTs for personally familiar face decisions ranged from 550 – 677 ms. However, these studies reported either no significant difference between recognition performance for (upright) unfamiliar and familiar faces (Anaki et al 2007), or fell short in providing information concerning the time required for unfamiliar face categorisation (Valentine and Bruce 1986; Kampf et al 2002; Caharel et al 2005), which has been found to vary between 400 and 1170 ms.[1] Studies supporting

[1] Furthermore, Herzmann et al (2004, experiment 2) found higher error rates for familiar (unprimed) faces accompanied by no RT differences between familiar and unfamiliar faces; Baird and Burton (2008, experiment 1) reported a speed/accuracy trade-off using famous and unfamiliar faces. Similarly, Boehm et al (2006) found longer, rather than shorter, RTs for (initial presentation of) familiar as compared to unfamiliar faces (780 ms versus 710 ms). Thus, face familiarity is not unequivocally associated with faster, or more efficient recognition performance. Even when considering the relative

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the notion of a familiarity-related processing benefit (accuracy, RTs) have reported substantially longer RTs. For instance, Baird and Burton (2008, experiment 2) reported ~775 ms for categorisation of bilaterally presented famous faces; Herzmann et al (2004, experiment 1) reported 855 ms for famous, and 875 ms for personally familiar face categorisation.

A great deal of the reported variability is likely related to methodological differences between studies. One important aspect refers to the type of familiarity assessed (public, personal, experimentally learned). Numerous studies have utilised famous faces to investigate familiarity-related processing differences, although this seems somewhat questionable, for two reasons at least. First, in any given study there will be a wide range of variation regarding the degree of exposure to (ie familiarity with) famous faces—both between and within participants. Second, the images of famous individuals used are often 'iconic' pictures of celebrities (eg the iconic photographs of Marilyn Monroe, or Che Guevara). It has been suggested that recognising these images of famous faces may not call upon normal face recognition processes involved in the recognition of personally familiar faces (Tong and Nakayama 1999; Knappmeyer et al 2003; Carbon 2008). The limitation of image- as opposed to identity-based recognition may also apply to studies in which participants have been experimentally familiarised with face stimuli, at least when a single viewpoint or image of the face is used in training and recognition (eg Herzmann and Sommer 2007).

Other methodological considerations include factors such as the type of manual response required (bimanual versus unimanual), presentation duration, consideration of possible speed/accuracy trade-offs, as well as stimulus set size (two extreme instances are, eg, the use of only two personally familiar faces presented in Caharel et al 2005, or one famous and one unfamiliar face in eg experiment 3 of Lewis and Ellis 2000). Another important issue is that, although several studies involved multiple repetitions of a restricted stimulus set, or even larger ones, the effect of repetition on speeded responses in recognition tasks has been largely neglected. It is therefore difficult to assess the actual time required for face recognition because repetition of identical stimuli is likely to cause a substantial decrease of RTs, which should be taken into account (see eg Lewis and Ellis 2000). Additionally, studies differ with respect to subtleties in data analyses. For instance, the shortest RTs reported for unfamiliar and familiar face recognition were provided by Anaki et al (2007). In their study, however, RTs were corrected in that trials on which latencies were below/above 2.5 SDs were excluded from analyses. Finally, one should also note that the reported values usually refer to average, or at times median, RTs, which do not provide an answer to the question of the minimum time required to reliably categorise a face as familiar.

Unfortunately, electrophysiological studies have provided comparably inconsistent evidence regarding the time, and thus processing stages at which familiarity-related differences can be observed. Recordings of event-related potentials (ERPs) have to a large extent failed to find differences between familiar and unfamiliar faces for the face-sensitive component peaking between 140 and 180 ms at occipito-temporal sites (N170; eg Rossion et al 1999; Bentin and Deouell 2000; Eimer 2000; Schweinberger et al 2002). Although other studies suggest familiarity-related modulation of the N170 (or M170 in magnetoencephalography, MEG), the direction of effects is rather variable. Compared to unfamiliar faces, N170 increases have been reported for personally familiar (Caharel et al 2005, 2006; Kloth et al 2006; Wild-Wall et al 2008), or famous (Caharel et al 2002;

[1] (continued)
processing benefit within studies indicating a familiarity-related advantage, ie differences in RTs or error rates, the results are no less variable. As a matter of fact, the differences are at times extremely small as compared to the variability in absolute RTs across studies (see eg Ellis et al 1990, experiment 2: 13 ms difference between unprimed familiar and unfamiliar faces).

Harris and Aguirre 2008) faces. However, N170 decreases have also been reported (famous: Marzi and Viggiano 2007; personally familiar: Todd et al 2008). On the other hand, the evidence regarding later components occurring at about 250 ms and 400 ms after stimulus onset is more consistent. The N250r, which has been related to activation of face representation in long-term memory (Schweinberger et al 2002), is decreased for unfamiliar as compared to famous (Schweinberger et al 1995; Pfütze et al 2002), personally familiar (Herzmann et al 2004), and experimentally familiarised (Tanaka et al 2006) faces. Similarly, the N400 component that has been related to the semantic information associated with familiar faces (Paller et al 2000), is larger for familiar than unfamiliar faces (Bentin and Deouell 2000; Eimer 2000; Paller et al 2000). The inconsistent latency values and effects reported for familiar face categorisation at the neurophysiological level are just as difficult to account for as the variable RTs reported in behavioural studies, and may be attributed to any number or combination of factors.

Here, we reasoned that determining the minimum behavioural time required for face categorisation in the context of superior performance for familiar faces would help to clarify the heterogeneous behavioural findings. Furthermore, provided a paradigm with sufficiently high temporal sensitivity, the findings may prove beneficial with regard to constraining interpretations made on the basis of ERP studies. For instance, the observation of minimum response times between 200 ms and 300 ms for familiar face categorisation would support the notion of preceding familiarity-dependent neural responses.

Over the past years, Thorpe, Fabre-Thorpe, and colleagues have developed several paradigms and data analyses to clarify the speed of simple visual categorisation tasks, from stimulus onset to motor responses (eg Thorpe and Fabre-Thorpe 2001). In most of these experiments, participants are required to categorise visual scenes as containing an animal or not containing one (Thorpe et al 1996; Rousselet et al 2002; Macé et al 2005), or to detect the presence of other salient visual categories such as a vehicle (Van Rullen and Thorpe 2001), or a face (Rousselet et al 2003). A go/no-go response mode, with a lift of the finger as a go-response, has been used to reduce response time to its minimum (eg VanRullen and Thorpe 2001; Rousselet et al 2002).

Collectively, these studies have been able to provide more precise information with respect to the speed of visual processing. For instance, Thorpe et al (1996) demonstrated that while participants' mean RTs amounted to 445 ms when required to decide whether a briefly flashed image contained an animal, their minimum RT lay at 382 ms. Using the more sensitive finger lift (see above) go-response mode, rather than button press, Rousselet et al (2002) reported RTs of about 400 ms for detection of stimuli depicting animals, with the shortest latencies occurring 260 ms after stimulus onset. Supporting evidence using a similar paradigm was reported by Macé et al (2005), who found RTs of about 410 ms, with minimum RTs as short as 280 ms (see also Bokura et al 2002). VanRullen and Thorpe (2001) reported even shorter latencies in the context of a go/no-go animal – vehicle categorisation task. Above-chance-level performance was found for RTs as short as 250 ms, while the mean RT reported for animal categorisation was $\sim$360 ms.

In this study, taking into account the issues mentioned above, we sought to systematically and directly address the issue of the speed required for familiar and unfamiliar face categorisation, a response-time sensitive, one-alternative go/no-go categorisation paradigm as employed by Thorpe and colleagues. We tested participants who were all comparably personally familiar with the individuals included in the familiar face set, which was contrasted with a set of well-matched unfamiliar faces. Two experiments were conducted to investigate the speed of behavioural familiar face categorisation. They differed merely with respect to the type of faces requiring a go-response: personally familiar or unfamiliar faces in experiments 1 and 2, respectively. As in previous studies, identical stimuli were presented a number of times throughout the experiment (8 times in total).

Contrary to prior investigations, however, we took into consideration potential effects of stimulus repetition. In the light of the above-mentioned inconsistent findings regarding the processing advantage observed for familiar as opposed to unfamiliar faces, we aimed to assess whether familiarity would be associated with a consistent benefit in categorisation efficiency. Furthermore, we sought to specify the minimum time required to categorise faces based on their familiarity—which, we consider, may potentially pose constraints on the time course and unfolding of perceptual face processes (Rossion and Jacques 2011).

2 Methods

2.1 *Stimuli*

Full-face photographs of 26 students of the University of Louvain served as personally familiar face stimuli. These students graduated together in 2008 (Master degree in Psychology). All had been in the same classroom as a small group (total of 31 students) for about 2 years at the time of testing. For each familiar face, a corresponding unfamiliar one, matched for sex, and eye and hair colour was chosen from a larger database of faces. All images were adjusted so that the pupils were aligned horizontally, and a generic black 'sweater' was superimposed on each photograph so that clothing did not vary across stimuli (figure 1). Furthermore, for each familiar face, an unfamiliar-face photograph was adjusted to have exactly the same size. The images subtended approximately 250 pixels in width and 360 pixels in height, encompassing about 5.02 deg × 7.24 deg of visual angle.

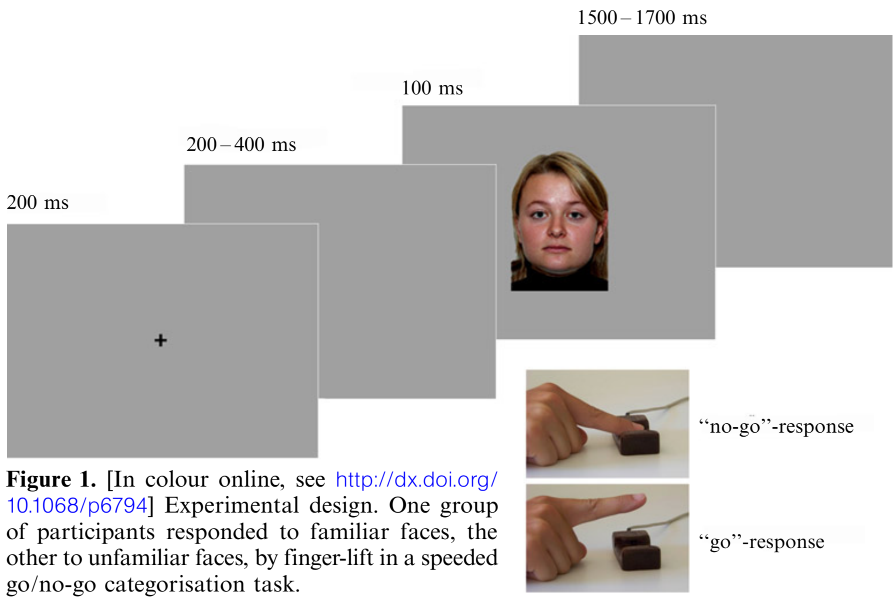


Figure 1. [In colour online, see http://dx.doi.org/10.1068/p6794] Experimental design. One group of participants responded to familiar faces, the other to unfamiliar faces, by finger-lift in a speeded go/no-go categorisation task.

All face images used in the experiment were equated for mean pixel luminance and contrast using the following procedure. Briefly, each image was first transformed from the *RGB* to the *YUV* colour space, which contains a luminance component (Y) and two chrominance components (U and V), allowing manipulation of pixel luminance and contrast independently of chrominance information. The pixel luminance and contrast of each image was adjusted by equating the mean and the standard deviation of the Y component's pixel intensity of all images. Each image was then back-transformed into *RGB* space. Note that only those pixels that belonged to the face depicted were taken into account in this procedure, with the light-gray background being equal for all images.

Furthermore, in order to verify that no perceived differences in image quality, or age of individuals depicted, may have varied across the groups of stimuli used, the images were categorised by an independent group of participants (who did not participate in the speeded go/no-go familiarity judgment task below and were unfamiliar with the faces; $n = 6$, three males, mean age: 27 ± 2 years, all right-handed). These participants (S1 – S6) performed an age categorisation task (old versus young), and were additionally required to categorise the images according to an arbitrary criterion they could choose freely (order randomised across subjects). The results of these categorisation tasks showed that for categorisation by age only one participant (S3) did not categorise at random ($p < 0.001$); the same held for categorisation by an arbitrary feature (S6: $p = 0.04$). For the remaining five participants for each task, categorisation was at random (all ps > 0.09). Additionally, another group of independent observers ($n = 15$, nine females, mean age: 28 ± 4 years) also unfamiliar with the images of the faces depicted rated the stimuli for distinctiveness (for procedure see Moore and Valentine 1998). Analyses revealed that the two stimulus sets did not differ in terms of their perceived distinctiveness ($t_{25} = 1.31$, $p = 0.20$).

2.2 *Participants and procedure*

Seventeen participants from the same classroom (eleven females, three left-handed; all paid for participation) with normal or corrected-to-normal vision performed a go/no-go familiarity judgment task, which required speeded responses to individually presented face stimuli, by categorising them as familiar or unfamiliar (each participant saw his/her own face, as well as those of 25 of their classmates). Seated at a viewing distance of 100 cm from a computer monitor in a light- and sound-attenuated room, participants were requested to place the index finger of their dominant hand on a response pad (a plate with a pair of emitter – detector infrared diodes). They were instructed to indicate the presence of a target stimulus as accurately and quickly as possible by lifting their finger ("go"-response) and keeping their finger on the response pad if distractors were presented ("no-go"-response). For one group of participants familiar faces necessitated go-responses ($n = 11$, six females, two left-handed), while a second group had to lift their finger to unfamiliar faces ($n = 12$, seven females, one left-handed; of these twelve, six also participated in the previous task; however, both tasks were completed on different days—on average 60 ± 45 days later). The response time was measured from the onset of a stimulus to finger-lift from the response pad; stimuli were presented on a light-gray background using E-prime 2.0.

Trials commenced with presentation of a central cross (200 ms); after a 200 – 400 ms ISI a face stimulus appeared for 100 ms, followed by a blank screen (1500 – 1700 ms). Participants completed four consecutive blocks of equal length (104 trials). Within each block, the entire set of 52 faces (26 familiar) was presented at random in full, and then repeated (again with random stimulus presentation). This allowed post-experimental investigation of potential effects of repetition.

Thus, for each participant and face type requiring a response (familiar versus unfamiliar), 416 trials were subject to analysis. For both experiments, the frequencies of correct responses (finger-lift on "go" trials) and false alarms (response on "no-go" trials) as well as mean and median RTs were calculated. We first explored potential differential changes in processing speed across stimulus repetitions, and attempted to determine the minimum time (ie the earliest of 20 ms time bins) associated with reliably more hits than false alarms (see, eg, Fabre-Thorpe et al 2001).

3 Results

Across all stimulus presentations in both experiment 1 (targets: familiar faces), and experiment 2 (targets: unfamiliar faces), participants performed extremely well (average accuracy: 98% and 96%). An unmatched two-sample t-test (corrected for unequal sample sizes) was performed to compare RTs obtained in experiments 1 and 2. As not all subjects who participated in experiment 1 were available for testing in experiment 2, a between-subjects test was performed. This analysis revealed that participants responded more rapidly to personally familiar than to unfamiliar faces (mean: 510 versus 552 ms, $t_{21} = 4.35$; median: 494 versus 532 ms, $t_{21} = 4.20$, both ps < 0.001; see figure 2). For both experiments 1 and 2 there was no evidence of a speed/accuracy trade-off, as indicated by the lack of a (positive) correlation between accuracy and both mean RTs ($p = 0.36$, and $p = 0.76$), or median RTs ($p = 0.43$, and $p = 0.11$). Importantly, as half of the subjects in experiment 2 had previously participated in experiment 1 (albeit with a considerable interval between testing sessions; see above), we investigated whether there were significant differences between these two (sub)groups. Independent-sample t-tests revealed that overall they did not differ in terms of accuracy ($t_{10} = 0.72$, ns) or speed (mean: $t_{10} = 1.89$, $p = 0.09$; median: 1.76, $p = 0.11$).

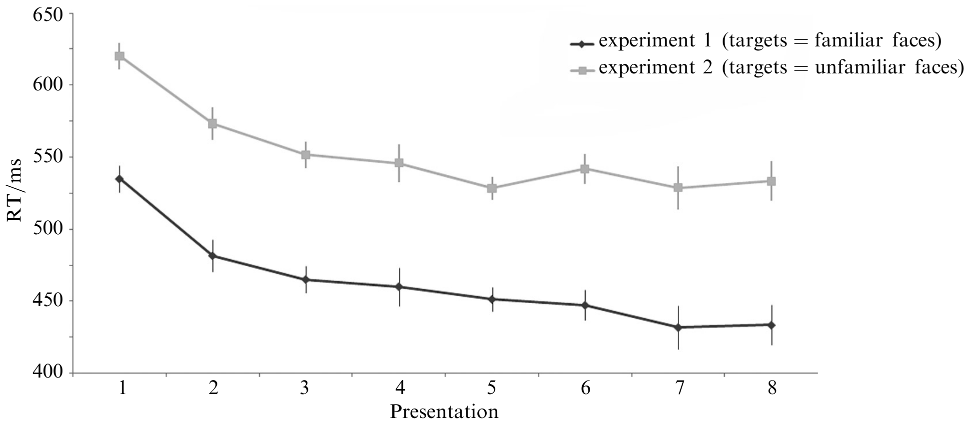


Figure 2. Repetition effects observed for experiments 1 and 2: response times as a function of stimulus presentation. Error bars indicate ± 1 SE.

3.1 *Repetition effects*

We aimed to investigate whether stimulus repetition would (differentially) impact the accuracy and speed of categorising (familiar and unfamiliar) faces. This was done specifically in light of previously reported RTs reflecting the average across multiple stimulus repetitions (see introduction).[(2)] To this end, ANOVAs were conducted on accuracy scores and RTs, with familiarity (ie target type: familiar/unfamiliar) as a between-subjects factor, and presentation (ie repetition) as a within-subjects factor.

For accuracy rates, there was a main effect of familiarity ($F_{1,21} = 4.35$, $p = 0.049$), but no effect of presentation ($F_{7,147} = 1.53$, $p = 0.16$), and no interaction between the two factors ($F_{7,147} = 0.77$, ns). For RTs, again a main effect of familiarity was found (mean RTs: $F_{1,21} = 19.26$, median RTs: $F_{1,21} = 17.78$, ps < 0.0005), as well as a main effect of presentation (mean RTs: $F_{7,147} = 24.37$, median RTs: $F_{7,147} = 28.71$, ps < 0.0001).

[(2)] As some subjects who completed experiment 2 had previously participated in experiment 1, we first sought out to investigate whether differential effects of repetition would be observed in the subgroups of experiment 2 (which did not differ overall; see above). The ANOVA on accuracy scores revealed neither a main effect of familiarity ($F_{1,10} = 0.39$, ns), nor presentation ($F_{7,70} = 0.83$, ns), nor an interaction between the factors ($F_{7,70} = 1.20$, ns). With respect to RTs, the ANOVA revealed a main effect of presentation ($F_{7,70} = 8.38$, $p < 0.0001$; see analyses below) but not of group ($F_{1,10} = 0.29$, ns). Importantly, there was no interaction between the factors ($F_{7,70} = 0.81$, ns). Thus, given that prior participation in experiment 1 did not render any differences between the subjects who completed experiment 2 additionally or alone, the data of all subjects were collapsed and analysed as a group to investigate the effects of repetition.

As for accuracy scores, there was no interaction between the two factors ($F_{7,147} = 0.34$, ns), indicating that while RTs were shorter for experiment 1 (see above), the decrease in RTs with stimulus repetition was comparable across experiments (figure 2).

A-posteriori analyses (Scheffe test) indicated that the overall decrease in RTs with stimulus repetition was driven mainly by the larger RT decrease between the first and second presentation (for both mean and median RTs $p\text{s} < 0.001$; see figure 2, table 1). Additionally, for mean RTs there were significant differences between the 2nd and 5th, 7th, and 8th presentations, respectively ($p\text{s} < 0.02$); the same held for median RTs, as well as an additional significant difference between the 2nd and 6th presentation ($p\text{s} < 0.02$).

Table 1. Mean and median RTs (standard errors) for "go"-responses (collapsed across experiments 1 and 2) for each stimulus presentation.

RT	Presentation							
	1st	2nd	3rd	4th	5th	6th	7th	8th
Mean RT (in ms)	578 (18)	527 (18)	508 (14)	503 (14)	490 (12)	495 (14)	480 (14)	483 (14)
Median RT (in ms)	560 (16)	516 (17)	496 (15)	490 (13)	479 (11)	482 (13)	466 (12)	469 (13)

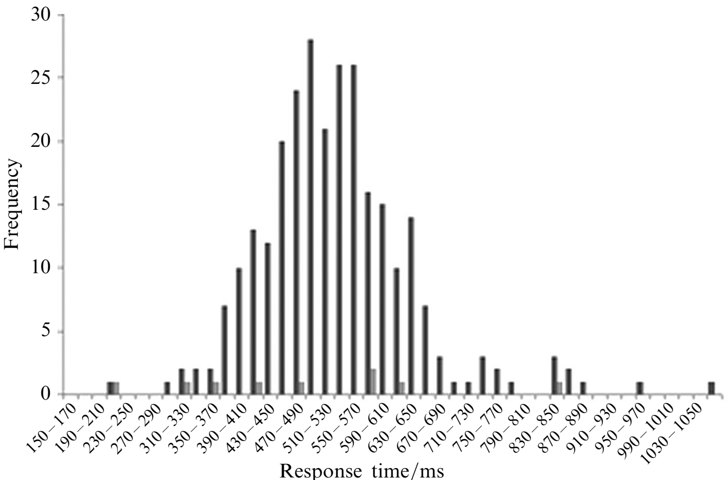
Given these observations, we sought to determine whether the effect of repetition—predominantly evident from the 1st to 2nd presentation—reflected a general decrease in RTs due to having become increasingly acquainted with the task. We carried out correlation analyses to assess the relationship between RTs and the number of trials completed using bootstrap tests of independence (owing to the limited sample size, which would render greater susceptibility to extreme values). The rationale was that task familiarisation should be observed across the first block of 52 stimuli (ie where no repetition had taken place, and 26 stimuli required a response) in the sense of a (negative) correlation between trials completed and RTs displayed.

We sampled the data points (ie the RTs from the eleven or twelve subjects provided on each trial, for experiments 1 and 2, respectively) with replacement, and then computed the Pearson correlation between number of trials and RTs (averaged across subjects). This process was repeated 999 times, leading to a distribution of boot-strapped Pearson correlation coefficients between the two variables. Then, 95% confidence intervals were computed using the adjustments suggested by Wilcox (2005). Finally, correlations were considered significant if their 95% confidence intervals did not include zero ($\alpha = 0.05$). For both experiments 1 and 2, no significant correlations were found—neither for the mean ($r = 0.75$, and $r = 0.47$), nor median ($r = 0.11$, and $r = 0.56$) RTs across the first 26 stimuli requiring a response—indicating that the repetition effects reported above cannot be accounted for by task familiarisation.

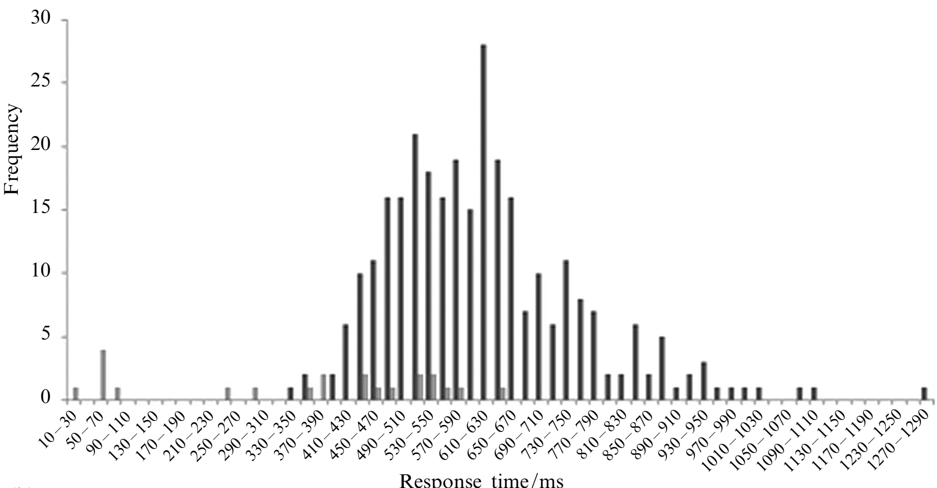
3.2 *Minimum and average response times for familiar and unfamiliar face recognition*

In light of the above findings we reasoned that for the following analyses only responses provided upon the first presentation of a given stimulus ought to be considered, as averaging RTs across all stimulus presentations would lead to a considerable underestimation of the time required for face recognition. This is especially important given our aim to determine both the minimum and average time required for familiar- and unfamiliar face categorisation. In order to determine the minimum time required to correctly categorise faces as familiar or unfamiliar, χ^2 tests of proportions were conducted separately for each 20 ms time bin. The minimum RT was considered as the first bin within which the number of correct responses significantly outnumbered the number of false alarms, and where this was also the case for all subsequent bins.

For experiment 1, the 370 – 390 ms bin was the first to contain significantly more hits than false alarms ($p = 0.03$); all the following bins contained significantly more correct responses (see figure 3). Averaging RTs for correct responses provided upon first presentation of each stimulus yielded mean RTs of 535 ms (median: 527 ms). For experiment 2, the first time-bin within which the number of hits was significantly higher than that of false alarms was the 410 – 430 ms bin. However, the difference failed to reach significance in the following bin (430 – 450 ms; $p = 0.08$). From the 450 – 470 ms bin on, all subsequent ones contained significantly more hits than false alarms (ps < 0.05; see figure 3). Averaging RTs for correct responses provided upon first presentation of each stimulus yielded mean RTs of 618 ms (median: 606 ms). Taken together these results indicate that in experiment 1 faces were correctly categorised as familiar about 80 ms faster than when unfamiliar faces were categorised in experiment 2; independent-sample t-tests confirmed this difference ($t_{21} = 7.69$, $p < 0.0001$).



(a)



(b)

Figure 3. Response time distributions for the first presentation of stimuli shown in (a) experiment 1 (targets = familiar faces) and (b) experiment 2 (targets = unfamiliar faces). The dark-gray and light-gray bars indicate the frequency of correct responses and false alarms per 20 ms time bin, respectively.

Given the limited sample size, we carried out percentile bootstrap analyses to confirm this difference. We sampled subjects with replacement, averaging the means across participants independently for each group of subjects (ie familiar faces = targets, or unfamiliar faces = targets), and then computed the difference between the means for the two tasks. This process was repeated 999 times, leading to a distribution of bootstrapped estimates of the mean difference between two conditions, averaged across subjects. Then the 95% confidence interval was computed ($\alpha = 0.05$). Again, the difference between the two sample means was considered significant if the 95% confidence interval did not include zero. Note that this bootstrap technique, which relies on an estimation of H1, tends to have more power than other robust methods (eg permutation tests and related bootstrap methods that evaluate the null hypothesis H0; Wilcox 2005). These analyses corroborated the results obtained with parametric statistics by showing an advantage for familiar-face recognition of 84 ms [CI: (23.42; 144.29)].

4 Discussion

The aim of the present study was to systematically and directly investigate the speed required to categorise faces in the realm of a manual go/no-go categorisation task. As participants responded either to personally familiar or unfamiliar faces we (i) avoided problems associated with the use of famous face stimuli, (ii) explored the potential of differential effects of repetition on familiar/unfamiliar-face recognition, while (iii) investigating familiarity-related differences in speed of face categorisation.

We found that familiar as well as unfamiliar face categorisation was influenced similarly by stimulus repetition, as reflected by the comparable decrease in RTs across individual stimulus presentations. Notably, irrespective of face familiarity, the largest effects of repetition were found between the 1st and 2nd stimulus presentations. Although correlation analyses conducted on trials involving 1st presentation of the face stimuli ruled out the possibility that this effect reflects participants becoming familiarised with the speeded go/no-go task, the source(s) of this improvement in speed with the number of repetitions is (are) unknown. It could be, for example, that representations become more robust over time, especially since the participants were not familiar with these particular photographs (ie images) at the beginning of the experiment. An experiment involving changes in the response procedure between stimulus presentations would help to understand the source of such effects. Irrespectively, it is likely that effects of repeated stimulus presentations not considered in previous studies of face categorisation influenced the reported results. The present findings further emphasise the importance of dissociating first, and subsequent stimulus presentations when attempting to make estimates concerning the minimum/average processing speed based on RTs obtained with a manual effector.

On the basis of our findings, and in line with previous investigations, we conclude that in a familiar/unfamiliar categorisation task faces can be reliably (manually) categorised as familiar at about 530 ms after stimulus onset on average, with the fastest responses occurring between 370 and 390 ms. For unfamiliar faces, speeded responses were relatively prolonged; overall they were categorised as unfamiliar within 620 ms, with significantly more hits than false alarms occurring 450 – 470 ms after stimulus onset. Importantly, the observed benefit for familiar, as compared to unfamiliar, face categorisation was fairly constant despite the aforementioned repetition-related decreases in RTs. This reinforces the fact that personal familiarity with faces differs fundamentally from familiarisation with face stimuli merely due to visual exposure.

Importantly, such rapid behavioural categorisation of faces (370 – 390 ms) provides an upper boundary for familiar face categorisation and thus has implications for the ERP literature on face processing, by constraining how early the effects of familiarity could be observed in these studies. In light of our findings and given the time required to execute a manual response (about 100 ms—see VanRullen and Thorpe 2001), the earliest familiarity-dependent modulation at the electrophysiological level could be expected at about 250 ms after stimulus onset. This value is consistent with a number of studies that have reported intermediate latency effects of face familiarity on the electrophysiological signal recorded from the scalp, namely on the N250r component, which is reduced for unfamiliar as compared to famous (Pfütze et al 2002; Schweinberger et al 1995), personally familiar (Herzmann et al 2004) or experimentally familiarised (Tanaka et al 2006) faces, and has been related to the activation of face representations in long-term memory (Schweinberger et al 2002; see also Jemel et al 1999). Our data are also in agreement with studies reporting rather late effects of face familiarity, occurring approximately 400 ms after stimulation at centro-parietal sites (Bentin and Deouell 2000; Eimer 2000; Paller et al 2000; Jemel et al 2003). However, the present findings suggest that this larger N400 for familiar than unfamiliar faces would reflect relatively late effects of face familiarity, for instance the activation of semantic information associated with faces (Paller et al 2000), rather than the categorisation of faces as being familiar.

However, our data are difficult to reconcile with studies reporting effects of face familiarity earlier than 250 ms after stimulus onset. For instance, some studies have reported very early differences between previously seen and novel faces, ie at 70 – 130 ms (Debruille et al 1998; George et al 1997) or even 40 – 90 ms (Morel et al 2009; Seeck et al 1997) after stimulus onset. Considering that our behavioural data were obtained with pictures of highly familiar faces, it is very unlikely that these early ERP effects reflect the genuine discrimination between familiar and unfamiliar faces, unless the two sets of stimuli differ substantially in terms of physical low-level properties. Similarly, studies reporting familiarity effects as early as 170 ms after stimulus onset (Caharel et al 2002, 2005, 2006; Jemel et al 2003; Kloth et al 2006; Marzi and Viggiano 2007; Harris and Aguirre 2008; Todd et al 2008; Wild-Wall et al 2008)—suggestive of activation of long-term face representations almost as early as the system has accumulated sufficient evidence to individualise the face percept (Jacques and Rossion 2006; Jacques et al 2007)—are incompatible with our findings. However, as elaborated on above, these findings should be regarded with caution, given the inconsistent nature of effect reported (N170 increase or decrease for familiar faces), and in light of a large number of studies that have failed to find effects of familiarity at this processing stage (eg Rossion et al 1999; Bentin and Deouell 2000; Eimer 2000; Schweinberger et al 2002).

Two important aspects require consideration. The first one is general and relates to the fact that the absolute level of RTs measured varies highly as a function of factors including eg task type, population sampled, etc, and applies to all studies conducted with the aim of determining absolute thresholds for any given type of decision. The second aspect concerns the ceiling effect observed in the present experiment. Our aim of investigating personally familiar and unfamiliar face categorisation across a group of individuals inherently posed restrictions with regards to the stimulus set size that could be used. Despite the enormous efficiency characteristic of personally familiar face recognition, we would assume that the use of a larger set of stimuli (from a wide range of social settings) would be associated with a larger number of false alarms. This in turn would allow a more reliable estimation of minimum RTs for face categorisation (eg Rousselet et al 2003 reported comparable accuracy scores, but presented several hundreds of stimuli, increasing the number of false-alarms observed). We would like to argue, however, that the consequence of false-alarms observed here reflecting only random error would be an overestimation of minimum RTs. Further work using other paradigms and/or techniques (eg Bacon-Macé et al 2007) will be required to address this issue and determine whether face categorisation can be achieved even faster than observed in the present study, which to date reports the fastest RTs to our knowledge.

Apart from these considerations, it must be emphasised that the nature of the processing differences observed for personally familiar compared to unfamiliar faces remains to be determined. The consistent advantage observed here may reflect familiarity-related facilitation of perceptual processing of faces (see eg Goto et al 2005). However, if a face can be categorised as familiar in 370 ms, the system is, from a logical point of view, able to discriminate between familiar and unfamiliar faces already at that latency. In other words, unfamiliar faces are somehow also detected at that latency. However, actively categorising a face as unfamiliar (ie a 'no' or 'rejection' response) may simply require a longer analysis and accumulation of more evidence before a decision is reached. The finding of relatively longer RTs for unfamiliar face categorisation does not provide an answer to the question whether observed speed differences are related to slower face processing (ie more analysis required for unfamiliar faces), reflect decision-based differences (eg participants are more hesitant to respond to an unfamiliar face) or are inherent to memory search (which, if involving a serial component, will be terminated earlier if a match is present). Future studies should address the impact of such factors, as well as eg extent of familiarity and distinctiveness (see eg Rakover and Cahlon 2001), preferably using methods recording face processing with a high temporal resolution.

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