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Research Report

How quickly do we learn new faces in everyday life? Neurophysiological evidence for face identity learning after a brief real-life encounter

Tsvetomila Popova and Holger Wiese *

Durham University, United Kingdom

A R T I C L E I N F O

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Faces learnt in a single experimental session elicit a familiarity effect in event-related brain potentials (ERPs), with more negative amplitudes for newly learnt relative to unfamiliar faces in the N250 component. However, no ERP study has examined face learning following a brief real-life encounter, and it is not clear how long it takes to learn new faces in such ecologically more valid conditions. To investigate these questions, the present study examined whether robust image-independent representations, as reflected in the N250 familiarity effect, could be established after a brief unconstrained social interaction by analysing the ERPs elicited by highly variable images of the newly learnt identity and an unfamiliar person. Significant N250 familiarity effects were observed after a 30-min (Experiment 1) and a 10-min (Experiment 2) encounter, and a trend was observed after 5 min of learning (Experiment 3), demonstrating that 5–10 min of exposure were sufficient for the initial establishment of image-independent representations. Additionally, the magnitude of the effects reported after 10 and 30 min was comparable suggesting that the first 10 min of a social encounter might be crucial, with extra 20 min from the same encounter not adding further benefit for the initial formation of robust face representations.

1. Introduction

When identifying known people from their faces, the human brain highly efficiently resolves a problem of considerable complexity, as we accurately recognise familiar faces from novel, never-before-seen images, even in highly challenging circumstances (e.g. Burton, Wilson, Cowan, & Bruce, 1999; Demanet, Dhont, Notebaert, Pattyn, & Vandierendonck, 2007; Hole, George, Eaves, & Rasek, 2002). At the same time, the recognition or even simultaneous matching of unfamiliar faces in seemingly ideal conditions is often challenging (e.g. Bruce et al., 1999; White, Kemp, Jenkins, Matheson, & Burton, 2014). These well-established findings beg the question of what makes familiar and unfamiliar face recognition so different, and part of the answer seems to be that we know

* *Corresponding author*. Department of Psychology, Durham University, South Road, Durham DH1 3LE, United Kingdom.
E-mail address: holger.wiese@durham.ac.uk (H. Wiese).

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what our friends, relatives, and colleagues look like in a wide variety of circumstances (e.g. with varying lighting, viewing angles, facial movements, but also varying hair/beard styles, make-up, weight, or health), while this kind of information is usually not available for somebody we have just met (Young & Burton, 2017, 2018). More formally, we have memory representations that are abstract from any particular instance, and therefore activated by a wide range of never-before-seen images, for familiar but not for unfamiliar faces, which allows efficient and image-independent recognition of the former but not the latter (Bruce, 1994; Kramer, Young, & Burton, 2018). But how are these familiar face representations initially established? Every familiar face has been unfamiliar and seen for the first time at some point in the past. Moreover, we constantly meet new people and have to regularly form new face representations which then allow recognition at a later time. At present, the neural processes underlying face learning, and particularly the time it takes to establish a novel, image-independent representation are not well understood. Here, we used event-related brain potentials (ERPs) to examine the temporal dynamics of face learning, as measured by the neural response to novel images of newly learnt and unfamiliar faces, and more specifically the amount of time during a first encounter that is needed for image-independent recognition.

Current theoretical work on face recognition and learning emphasises qualitative differences underlying familiar and unfamiliar face processing (Young & Burton, 2017, 2018). Unfamiliar face recognition is thought to strongly rely on so-called pictorial codes or representations, which closely resemble the appearance of a face in the specific situation it was seen. Recognition is therefore closely tied to this original encounter (Young, Hay, McWeeny, Flude, & Ellis, 1985), and, as a result, images that closely match this specific instance are well recognised, but even small deviances can have detrimental effects on recognition (e.g. Burton, White, & McNeill, 2010; Longmore, Liu, & Young, 2008). However, exposure to highly variable images of the same face, e.g. taken from different viewpoints, with different emotional expressions, and/or in different lighting conditions, enables people to learn which aspects remain stable across images (Burton, Jenkins, Hancock, & White, 2005) and how different the same face can look due to environmental factors or changes in the face itself (Burton, Kramer, Ritchie, & Jenkins, 2016; Jenkins, White, Van Montfort, & Mike Burton, 2011). Repeated exposure to highly variable images of a face thus enables the transition from pictorial to so-called structural codes which are abstract (in the sense that they do *not* represent a specific image) and allow the successful reconciliation of highly variable exemplars as belonging to the same identity (Young et al., 1985). Therefore, getting to know a face's idiosyncratic variability appears to be a crucial aspect of face learning (Jenkins et al., 2011; Kramer, Jenkins, Young, & Burton, 2017). In support of this theoretical argument, it has been found that a wider range of within-person variability facilitates face learning. For instance, exposure to high-variability images (which capture both situational changes such as different facial expressions, distance from the camera, or different head angles, and longer-term changes due to ageing, health, hairstyle, camera characteristics etc.) results in more effective learning relative to low-variability images (stills taken from a single video which capture only situational changes) (Ritchie & Burton, 2017). However, it is as yet unclear how much exposure to a new face is necessary to learn someone's idiosyncratic variability well enough for image-independent recognition to occur.

ERP studies on face recognition have consistently shown that familiar faces elicit more negative amplitudes than unfamiliar identities at occipito-temporal electrode sites starting at approximately 200 ms after stimulus onset (e.g. Bentin & Deouell, 2000; Gosling & Eimer, 2011; Saavedra, Iglesias, & Olivares, 2010). This so-called N250 familiarity effect is typically assumed to reflect access to long-term visual face representations, but, importantly, pre-experimentally unfamiliar faces can elicit this effect following a learning task (Andrews, Burton, Schweinberger, & Wiese, 2017; Kaufmann, Schweinberger, & Burton, 2009; Tanaka, Curran, Porterfield, & Collins, 2006; see also Zimmermann & Eimer, 2013). In many cases, however, these experiments have relied on low-variability stimuli, such as images or videos with relatively small or highly controlled changes in viewpoint or facial expressions (e.g. Kaufmann et al., 2009; Tanaka et al., 2006; Zimmermann & Eimer, 2013), therefore reducing a critical aspect of face learning (Kramer et al., 2017; Ritchie & Burton, 2017). The extent to which the observed effects represented the activation of fully image-independent representations is therefore somewhat unclear. In an attempt to overcome this limitation, Andrews et al. (2017) presented participants simultaneously with 20 different, highly variable images of two 'to-be-learnt' identities that were taken on many different occasions. Clear N250 effects were observed after a brief exposure to these stimuli, and importantly, these effects were highly similar when using the same images as presented during learning or completely novel images of the learned identities at test. However, while introducing substantial within-person variability to the learning and testing phases, the high variability of the stimuli used in this study arguably more closely resembled learning a face from a number of different occasions. As noted above, while many dimensions of facial variability change during a given real-life encounter (such as facial expressions, gaze, viewing angle), other aspects (such as weight, age, health, hairstyle, make-up etc.) remain more stable. As yet, it remains unknown whether the variability experienced during a single brief encounter is sufficient to form a robust representation that enables the recognition of novel, highly variable instances of the face.

Interestingly, researchers have started to study exposure to real-life variability by using more naturalistic learning procedures. For instance, recent studies found stronger neural responses for previously unfamiliar people following 4 h of real-life exposure over eight weeks (Campbell & Tanaka, 2021) and after three real-life 1-h learning sessions over three consecutive days (Ambrus, Eick, Kaiser, & Kovács, 2021). Recently, an fMRI study demonstrated that even shorter real-life exposure can lead to face learning (Sliwinska et al., 2022). In this study, participants interacted with a pre-experimentally unfamiliar person in three 10-min sessions spread across two weeks. The authors report improved accuracy in image matching of newly learnt faces after the second session. Moreover, significant changes in right-hemispheric cortical face-processing areas (fusiform face area, occipital face area, posterior superior temporal sulcus, amygdala) and the hippocampus were observed following the last interaction. These studies demonstrate that ecologically more valid experimental paradigms can be used to advance our understanding of the establishment of new face representations. However, as noted above, it still remains unclear whether a single social encounter can produce a learning response.

Relatedly, the time course of face learning has not been systematically examined. Previous studies have demonstrated neural correlates of face learning after single lab-based learning sessions, but the minimal exposure time necessary to form robust image-independent representations in more naturalistic circumstances has not been established. It has been demonstrated that the N250 effect is modulated by the degree of familiarity, as the effect elicited by well-known celebrities is larger relative to recently learnt faces (Andrews et al., 2017), and personally highly familiar faces elicit a stronger N250 compared to famous people (Wiese, Hobden, et al., 2022). However, the trajectory of how the effect builds up over time, and particularly the time point at which it first emerges, remain unclear.

Of note, familiarity effects in ERPs are not restricted to the N250 time range. Previous work has shown that the ERP familiarity effect for highly familiar faces further increases following the N250 time range and peaks between 400 and 600 ms (Wiese, Tüttenberg, et al., 2019). We have suggested that this so-called Sustained Familiarity Effect (SFE) reflects the integration of visual with additional person-related semantic and/or episodic information, as, on the one hand, the scalp distribution of the SFE and the N250 effect are very similar, but on the other hand the SFE is differentially modulated by experimental manipulations (Wiese, Ingram, et al., 2019) and therefore functionally not identical to the N250. Recently, we (Popova & Wiese, 2022) reported that two months of familiarity were sufficient to elicit a familiarity effect in the SFE time window but the magnitude of the effect was substantially smaller than in previous studies on personally highly familiar faces, and not significantly larger than the N250 effect. So far, no studies have examined the SFE following brief, initial learning of a new face. However, in line with our interpretation of the SFE, we would not expect that a brief interaction with a pre-experimentally unfamiliar person results in increased ERP familiarity effects following the N250 time range.

The present experiments investigated whether an N250 familiarity effect, reflecting the activation of image-independent face representation, can be established following brief naturalistic exposure to a pre-experimentally unfamiliar identity. For this purpose, we presented participants with a previously unfamiliar person in a short one-to-one social encounter followed by an EEG test session in which novel, naturally varying "ambient" images (see Fig. 1 for examples) of the newly learnt and of an unfamiliar identity were presented. During learning, participants were exposed to within-person variability on those dimensions in which parameter values naturally shift during an initial encounter (e.g. different viewing angles, facial expressions, eye gaze, speech movements etc.), while other sources of variability remained constant (e.g. lighting, age, health, weight, make-up, hairstyle etc.). Our experiments, therefore, examined whether variability in the former dimensions was sufficient to enable recognition from photos that vary on the latter dimensions as well, which would support the abstract nature of the underlying representations. In Experiment 1, participants interacted with the 'to-be-learnt' person for 30 min which resulted in significant N250 familiarity effects. In an attempt to estimate the minimum exposure necessary to elicit

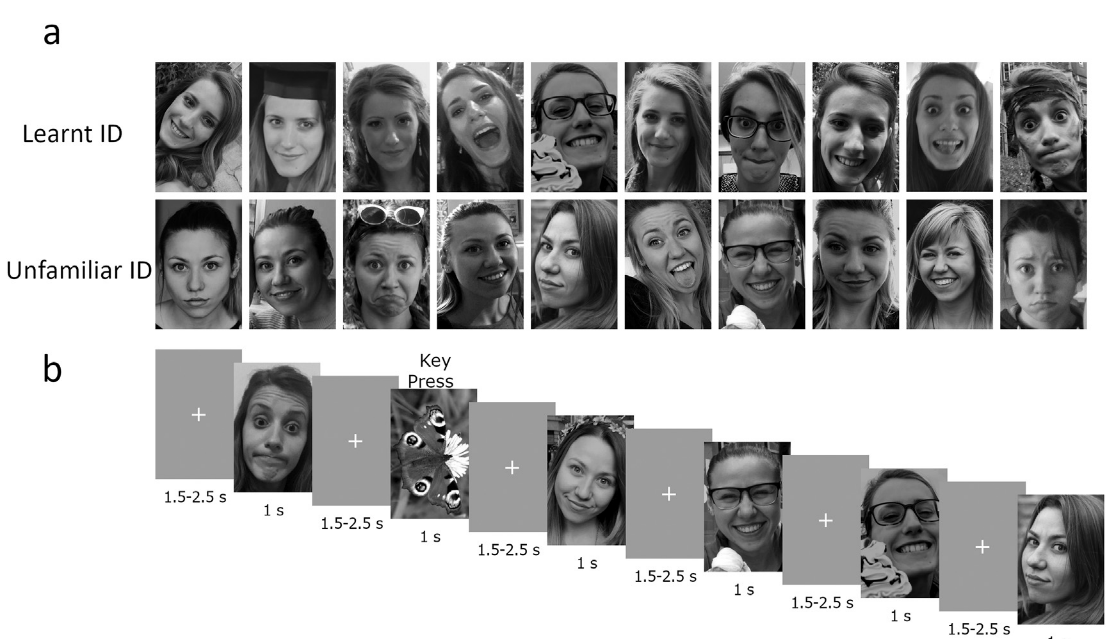

Fig. 1 – a) Examples of ambient images from two identities. b) Trial structure of the experiment. Images are published with the permission of the depicted persons.

learning effects, we then reduced the duration of the learning phase to 10 min in Experiment 2 and 5 min in Experiment 3. While 10 min were sufficient to elicit effects comparable to Experiment 1, only marginal effects were detected after a 5-min interaction. A final experiment was conducted as a control which confirmed that the observed effects indeed resulted from the social interaction prior to testing rather than learning during the EEG session.

2. Experiment 1: 30-min learning phase

2.1. *Method*

We report how we determined our sample size, all data exclusions, all inclusion/exclusion criteria, whether inclusion/exclusion criteria were established prior to data analysis, all manipulations, and all measures in the study.

2.1.1. *Participants*

Required sample size was estimated in a power analysis using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) based on the difference between newly learnt and unfamiliar faces in a previous study (Andrews et al., 2017; late N250 effect for the learnt/different condition, TP9/TP10 only; paired-sample test, two-sided, dz = .84, $1-\beta = .95$), which suggested a sample size of $N = 21$. Our actual sample consisted of 24 students at Durham University (15 female, nine male; age $M = 20.5$, $SD = 1.3$). One additional participant was excluded due to technical problems during EEG recording. All participants were right-handed according to a modified version of the Edinburgh Handedness Inventory (Oldfield, 1971), had normal or corrected-to-normal vision, and did not take central-acting medication. They gave written informed consent to participate and received course credit or a monetary reward of £7.50/h. The study was approved by the ethics committee of Durham University's Department of Psychology.

2.1.2. *Stimuli*

The stimuli consisted of 50 naturally varying "ambient" images showing the faces of each of four 'to-be-learnt' identities (three female, one male; the confederates) and four additional unfamiliar identities that were pairwise matched for gender, approximate age, and approximate hair colour and style. All depicted persons were fully informed about the purposes of the experiment and voluntarily provided images of themselves which were cropped around the head, resized to 190×285 pixels (corresponding to approximately 5×7.5 cm image size on the screen), converted to grayscale, and matched for luminance using the SHINE toolbox (Willenbockel et al., 2010; see Fig. 1 for examples). Eight images of butterflies were used as targets to create a task demand. Confederates were recruited from the student research assistants working in the Durham Psychology EEG lab at the time of the experiment. Three confederates were year two and year three undergraduate Psychology students (unlike our participants who were mostly year one students), and the fourth confederate was a postgraduate student. All participants were unfamiliar with the assigned confederates in all cases.

2.1.3. *Procedure*

The study consisted of a learning phase and a subsequent EEG test session. One of the four confederates was randomly chosen as the to-be-learnt person for each of the participants, who were told that they would have a chat with one of the research assistants from the lab. Participants were also told prior to the learning session that they would later be presented with images of faces and that some of these faces might be familiar. During the learning phase, the confederate interacted with the participant for 30 min in a naturalistic face-to-face conversation. This was carried out in a room close to the EEG laboratory, with only the participant and the confederate present. To allow for a more naturalistic conversational situation, the discussion during the learning phase was not scripted and no specific instruction to watch the face was given to the participant. However, confederates had to ensure that their face was visible. Typical conversation topics included the participants' experiences at university (e.g. with their colleges, societies, sports teams etc.), how they find their course, hobbies, where they are from, or their living situation. As would be expected in a natural conversation, both the participants and confederates asked for and provided information about these topics. Accordingly, participants learned identity-specific information about the confederates during the interaction.

Immediately following the learning phase, participants were directly taken to the EEG laboratory (not allowing any further interaction with the confederate), prepared for EEG recording (taking approximately 15 min), and seated in an electrically shielded chamber (Global EMC™) with their head resting on a chinrest 80 cm from a computer monitor. Fifty photos each of the newly learnt confederate and of the unfamiliar person from the same pair, as well as 16 trials with pictures of butterflies were presented in random order (Fig. 1). Accordingly, in this and all following experiments, each participant was presented with images of two different identities. The images were presented using E-prime (Psychology Software Tools, Pittsburgh, PA) at a visual angle of $3.6° \times 5.4°$ on a uniform grey background in the centre of the screen for 1,000 ms. Trials were separated by a 1,500–2,500 ms fixation cross (2,000 ms on average). Participants were instructed to watch the screen at all times and to press a button in response to images of butterflies using the right index finger. Both accuracy and speed were emphasised. The EEG part of the experiment took approximately 6 min.

The main experiment was followed by a short rating task assessing the visual recognisability of the identities. The participants were simultaneously presented with eight randomly selected images of each of the two identities and asked how likely they would recognise the person on a scale of 1 *(highly unlikely)* to 5 *(highly likely)*.

2.1.4. *EEG recording and analysis*

64-channel EEG (EEGo, ANT Neuro, Enschede, The Netherlands) was recorded using sintered Ag/Ag-Cl electrodes at a sampling rate of 1024 Hz from DC to 200 Hz. AFz was used as the ground electrode and CPz served as the recording reference. Blinks were corrected using the algorithm implemented in BESA Research Software (Version 6.3;

Grafelfing, Germany). Data were segmented into epochs from −200 to 1,000 ms relative to stimulus onset, with the first 200 ms serving as a baseline. Artefact rejection was implemented using a 100 μV amplitude threshold and a 75 μV gradient criterion. The remaining trials were re-referenced to the common average reference and averaged for the two experimental conditions. The average number of trials was 47 (±4.3 SD, min = 34) for learnt and 47 (±4.3 SD, min = 33) for unfamiliar faces.

Similar to previous work on face learning (see Andrews et al., 2017), early (200–300 ms) and late (300–400 ms) N250 time windows were analysed at occipito-temporal electrodes TP9 and TP10. Moreover, the SFE was analysed between 400 and 600 ms at the same electrodes (see Wiese, Tüttenberg, et al., 2019). As we had no a priori hypotheses about the lateralisation of potential learning effects, paired-sample *t*-tests on data averaged across left- and right-hemispheric electrodes were run separately for each time range to test our hypotheses of learning effects with more negative amplitudes for newly learnt relative to unfamiliar faces. Repeated-measures ANOVAs with an additional hemisphere factor and analyses of the N170 time range are reported in Supplementary materials. Following an estimation approach in data analysis (e.g. Cumming, 2012), effect sizes and appropriately-sized confidence intervals (CIs) are reported throughout. Cohens' *d* was bias-corrected (d_{unb}) and calculated using the mean standard deviation rather than the standard deviation of the difference as the denominator. 95% CIs for d_{unb} were calculated using ESCI (Cumming, 2012). To compare the magnitude of familiarity effects against each other, we ran three paired-sample *t*-tests for familiarity effects in the three consecutive time windows. As we expected no significant differences, we additionally ran Bayesian tests to gain potential evidence for the null hypothesis. Finally, to fully explore the data, we ran mass univariate tests comparing learnt and unfamiliar face conditions at all electrodes and time points.

The study procedure and analyses were not pre-registered before data collection. All study data and analysis code are publicly available on the Open Science Framework platform (https://osf.io/mz6qb/). The conditions of our ethical approval do not permit the public archiving of the photos of the facial identities used in this study and the images cannot be shared with anyone outside the author team. Images of selected individuals who have provided their explicit written consent are used as examples in Fig. 1.

2.2. Results

The learnt identity was rated significantly higher in visual recognisability relative to the unfamiliar identity, $M_{diff} = 2.67$, 95% CI [2.14, 3.19], t (23) = 10.54, $p < .001$, $d_{unb} = 2.79$[1] (Table 1).

Visual inspection of the grand average ERPs suggested more negative amplitudes for the newly learnt in comparison to the unfamiliar face in all analysed time windows (Fig. 2—30 min). A *t*-test in the 200–300 ms time range yielded a trend in this direction, $M_{diff} = .58$ μV, 95% CI [−.05, 1.21], t (23) = 1.90, $p = .070$, $d_{unb} = .14$, 95% CI [−.01, .31]. A corresponding test conducted in the 300–400 ms range demonstrated significantly more negative amplitudes for the learnt identities relative to the unfamiliar faces, $M_{diff} = .74$ μV, 95% CI [.02, 1.46], t (23) = 2.13, $p = .044$, $d_{unb} = .17$, 95% CI [.01, .33]. Similarly, in the 400–600 ms window (SFE) ERP amplitudes for the learnt faces were more negative than for the unfamiliar faces, $M_{diff} = .90$ μV, 95% CI [.07, 1.72], t (33) = 2.26, $p = .034$, $d_{unb} = .25$, 95% CI [.02, .49].

There were no significant differences between the familiarity effects in the early and late N250, $M_{diff} = .16$ μV, t (23) = .67, $p = .511$, $d_{unb} = .10$, early N250 and the SFE, $M_{diff} = .32$ μV, t (23) = 1.54, $p = .137$, $d_{unb} = .18$, and the late N250 and the SFE, $M_{diff} = .16$ μV, t (23) = .77, $p = .452$, $d_{unb} = .08$. Bayesian tests provided moderate support for the null hypothesis for the early versus late N250, $BF_{01} = 3.81$, error % = .03, and late N250 versus SFE comparisons, $BF_{01} = 3.58$, error % = .03. For the early N250 versus SFE comparison, there was weak support for the null, $BF_{01} = 1.65$, error % = .03.

Table 1 – Mean ratings for visual recognisability for the learnt ID and the unfamiliar ID. Visual familiarity was assessed on a scale from 1 (very low familiarity) to 5 (very high familiarity).

	Learnt ID		Unfamiliar ID	
	M	SD	M	SD
Experiment 1: 30 min	4.17	.92	1.50	.93
Experiment 2: 10 min	3.62	.99	1.50	.83
Experiment 3: 5 min	2.88	1.41	2.00	1.23
Experiment 4: Control	1.85	.99	1.71	.87

3. Experiment 2: 10-min learning phase

3.1. Method

3.1.1. Participants

We tested 34 under- and postgraduate students at Durham University (27 female, seven male; age $M = 21$ years, $SD = 5.1$; 29 right-, five left-handed). This sample size was determined in a power analysis based on the late N250 effect observed in Experiment 1 (paired-sample test, one-tailed, dz = .44, $1 - \beta = .8$) using G*Power (Faul et al., 2007). Selection criteria and compensation were identical to Experiment 1. The study was approved by Durham University's Department of Psychology ethics committee.

3.1.2. Stimuli and procedure

Stimuli consisted of 50 images of each of six identities (four female, two male; four undergraduate and two postgraduate research assistants in the EEG lab at the time of testing), which were pairwise matched for gender. Each participant was tested with one pair, with one identity as the 'to-be-learnt' person while the other was used as the unfamiliar face. As both members of a pair were learnt by different participants, the same images were used in the learnt and the unfamiliar

[1] Please note ESCI only provides CIs when the *d* value is between −2 and 2 (see Cumming, 2012, p. 306–307).

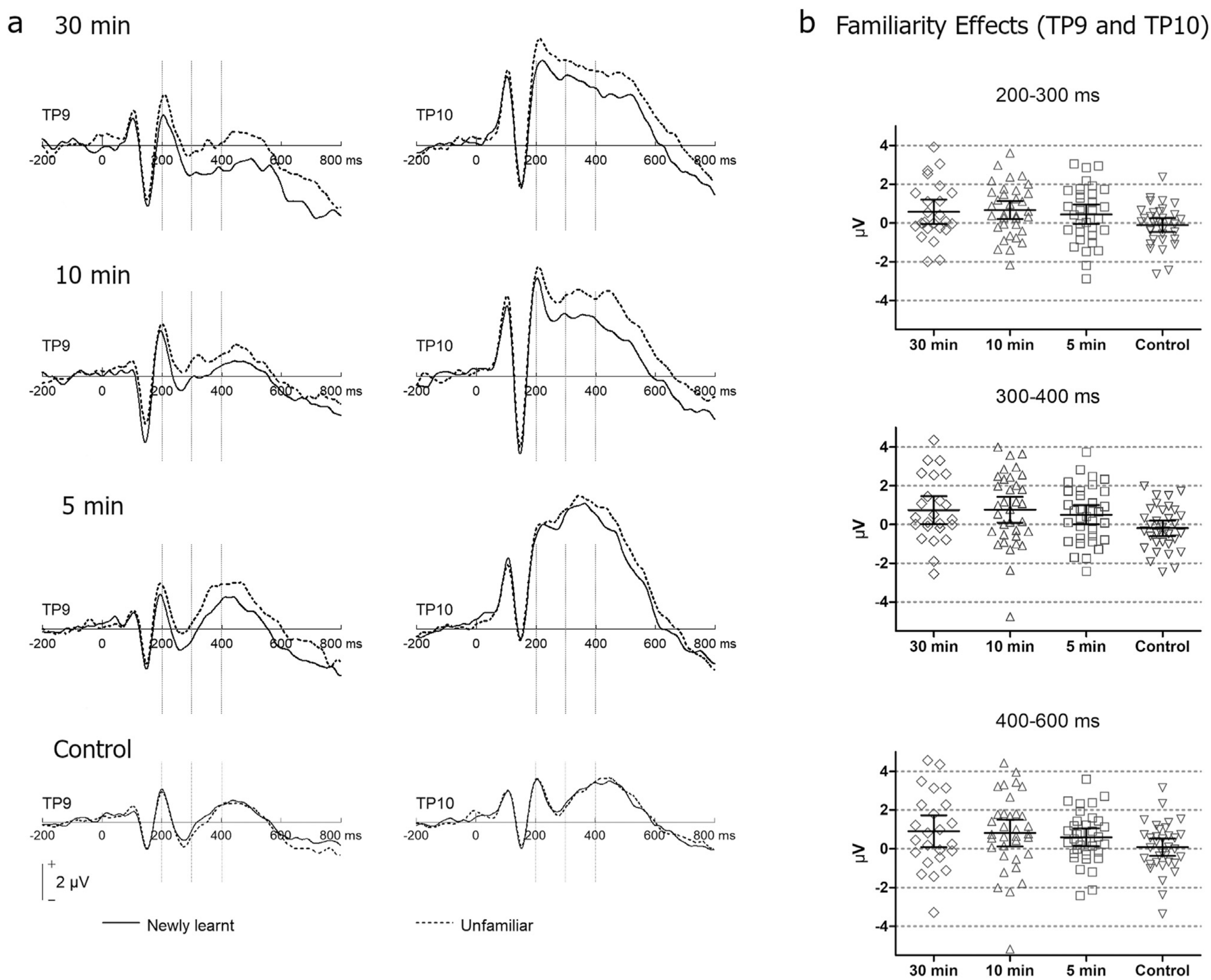

Fig. 2 – a) Grand average ERPs (30 min: N = 24; 10 min: N = 34; 5 min: N = 34; Control: N = 34) at left and right occipito-temporal channels TP9 and TP10 for the newly learnt vs. unfamiliar faces for all experiments. b) Individual familiarity effects (symbols) and mean familiarity effects with 95% CIs (solid lines) shown separately for the three time ranges of interest.

conditions across participants. Each identity served as the 'to-be-learnt' person for at least three participants. Stimulus editing was identical to Experiment 1.

The experimental procedure, as well as EEG recording and data analysis, were analogous to Experiment 1, with the exception that the learning phase was reduced to 10 min. Moreover, due to UK Covid-19 regulations, and specifically the requirement to wear face masks indoors, the learning sessions for Experiment 2 were conducted outside the Durham Psychology Department. The average number of trials was 48 (±3.3 SD, min = 36) for learnt and 48 (±2.3 SD, min = 43) for unfamiliar faces.

3.2. *Results*

The learnt identity was rated as significantly more visually recognisable than the unfamiliar identity, $M_{diff} = 2.12$, 95% CI [1.71, 2.53], $t\ (33) = 10.51$, $p < .001$, $d_{unb} = 2.28$ (Table 1).

ERP results are depicted in Figs. 2–10 min. Similar to Experiment 1, the newly learnt face elicited more negative amplitudes than the unfamiliar face in the 200–300 ms time range, $M_{diff} = .67\ \mu V$, 95% CI [.20, 1.13], $t\ (33) = 2.91$, $p = .006$, $d_{unb} = .20$, 95% CI [.06, .35], in the 300–400 ms time range, $M_{diff} = .76\ \mu V$, 95% CI [.10, 1.42], $t\ (33) = 2.34$, $p = .026$, $d_{unb} = .24$, 95% CI [.03, .46], as well as in the 400–600 ms time window, $M_{diff} = .82\ \mu V$, 95% CI [.13, 1.51], $t\ (33) = 2.40$, $p = .022$, $d_{unb} = .31$, 95% CI [.05, .59].

There were no significant differences between early and late N250, $M_{diff} = .09\ \mu V$, $t\ (33) = .57$, $p = .575$, $d_{unb} = .06$, early N250 and the SFE, $M_{diff} = .15\ \mu V$, $t\ (33) = .67$, $p = .506$, $d_{unb} = .09$, and late N250 and the SFE, $M_{diff} = .55\ \mu V$, $t\ (33) = .32$, $p = .749$, $d_{unb} = .03$. These results were further supported by Bayesian tests which revealed moderate support for the null hypothesis for the early versus late N250, $BF_{01} = 4.69$, error % = .04, early N250 versus SFE, $BF_{01} = 4.41$, error % = .04, and late N250 versus SFE comparisons, $BF_{01} = 5.19$, error % = .04.

4. Experiment 3: 5-min learning phase

4.1. Method

4.1.1. Participants

We tested 34 under- and postgraduate students at Durham University (30 female, four male; age $M = 19.3$ years, $SD = 2$; 32 right-, two left-handed). Selection criteria and compensation were identical to Experiment 1. Two participants had taken part in Experiment 2 but interacted and were tested with different identities. The study was approved by Durham University's Department of Psychology ethics committee.

4.1.2. Stimuli and procedure

Stimuli consisted of 50 images of each of four female identities (undergraduate research assistants in the EEG lab at the time of testing) who were paired up as in Experiment 2. Familiarity was balanced across participants, and each identity served as the 'to-be-learnt' person for at least eight participants. Stimulus editing was identical to Experiment 1.

The experimental procedure, as well as EEG recording and data analysis, were analogous to Experiment 1, but the learning phase was reduced to 5 min. As in Experiment 2, learning sessions took part outside the Durham Psychology building. The average number of trials was 46 (±3.9 SD, min = 35) for learnt and 46 (±4.0 SD, min = 36) for unfamiliar faces.

4.2. Results

The learnt identity was rated significantly higher in recognisability relative to the unfamiliar identity, $M_{diff} = .88$, 95% CI [.38, 1.39], $t\ (33) = 3.54$, $p = .001$, $d_{unb} = .65$, 95% CI [.26, 1.07] (Table 1).

Visual inspection of the grand average ERPs again revealed more negative amplitudes for the newly learnt face in comparison to the unfamiliar face in all time windows of interest (see Figs. 2–5 min). However, the effect appeared somewhat reduced relative to Experiments 1 and 2. Analysis in the N250 time range yielded trends towards familiarity effects, both in the 200–300 ms, $M_{diff} = .45$ μV, 95% CI [−.05, .95], $t\ (33) = 1.81$, $p = .079$, $d_{unb} = .15$, 95% CI [−.02, .33], and in the later 300–400 ms time range, $M_{diff} = .50$ μV, 95% CI [−.004, 1.00], $t\ (33) = 2.02$, $p = .052$, $d_{unb} = .17$, 95% CI [−.001, .35]. There was a significant familiarity effect in the later 400–600 ms time range, $M_{diff} = .59$ μV, 95% CI [.13, 1.05], $t\ (33) = 2.61$, $p = .014$, $d_{unb} = .25$, 95% CI [.05, .45].

Further analyses revealed no significant differences between the effects in the early and late N250, $M_{diff} = .05$ μV, $t\ (33) = .38$, $p = .709$, $d_{unb} = .03$, early N250 and the SFE, $M_{diff} = .14$ μV, $t\ (33) = .65$, $p = .521$, $d_{unb} = .10$, and the late N250 and the SFE, $M_{diff} = .09$ μV, $t\ (33) = .55$, $p = .584$, $d_{unb} = .07$. There was moderate support for the null hypothesis for the early versus late N250, $BF_{01} = 5.09$, error % = .04, early N250 versus SFE, $BF_{01} = 4.48$, error % = .04, and late N250 versus SFE comparisons, $BF_{01} = 4.72$, error % = .04.

5. Experiment 4: control experiment

5.1. Method

5.1.1. Participants

The sample consisted of 34 under- and postgraduate students at Durham University (27 female, six male, one non-binary; age $M = 19.0$ years, $SD = 1.3$; 30 right-, four left-handed). Two additional participants were excluded due to technical problems during EEG recording. Selection criteria and compensation were identical to Experiment 1. The study was approved by Durham University's Department of Psychology ethics committee.

5.1.2. Stimuli and procedure

The stimuli were identical to Experiment 3. The experimental procedure was analogous to Experiment 3 but there was no learning phase, and accordingly, all identities were unfamiliar to the participants. Each participant was randomly assigned to one version of the experiment, in which one specific pair of "learnt" and unfamiliar IDs from Experiment 3 was presented. Data was then analysed as if the "learnt" ID had been familiarised, although in fact both identities were unfamiliar. The ID combinations and the number of times each ID appeared in the two conditions were identical to Experiment 3 (see Experiment 2 in Wiese et al., 2019; for an analogous procedure). EEG recording and data analysis were identical to Experiment 1. The average number of trials was 48 (±4.0 SD, min = 30) for "learnt" and 47 (±3.7 SD, min = 33) for "unfamiliar" faces.

6. Results

As expected, there was a non-significant difference in visual recognisability between the two identities, $M_{diff} = .15$, 95% CI [−.08, .38], $t\ (33) = 1.30$, $p = .201$, $d_{unb} = .15$, 95% CI [−.08, .40] (Table 1).

Visual inspection of the grand average ERPs did not suggest any differences between the identities in any of the time windows (see Fig. 2—Control). Analyses confirmed this observation by revealing no significant differences between the conditions in the 200–300 ms, $M_{diff} = .10$ μV, $t\ (33) = .59$, $p = .562$, $d_{unb} = .04$, 300–400 ms, $M_{diff} = .19$ μV, $t\ (33) = 1.01$, $p = .322$, $d_{unb} = .06$, and 400–600 ms time ranges, $M_{diff} = .08$ μV, $t\ (33) = .36$, $p = .724$, $d_{unb} = .03$. Additionally, we ran Bayesian tests to examine our a priori prediction of non-significant differences between the two conditions which revealed a moderate support for the null hypothesis in the 200–300 ms, $BF_{01} = 4.64$, error % = .04, 300–400 ms, $BF_{01} = 3.42$, error % = .04, and 400–600 ms time windows, $BF_{01} = 5.13$, error % = .04.

7. Exploratory analysis

To fully explore the data beyond the predicted effects at a priorly defined electrode positions and time windows, mass univariate analyses of the within-participant comparisons of learnt versus unfamiliar faces were run for each time point and channel for all four experiments (see Fig. 3). The strongest familiarity effects were observed in the 10-min condition (Experiment 2). Systematic differences between the newly learnt and the unfamiliar identities began approximately 200 ms after stimulus presentation. In Experiment 3, stronger familiarity effects were observed over the central and parietal channels, presumably reflecting the opposite end of the dipole underlying occipito-temporal effects. No systematic differences were observed in our control experiment (Experiment 4). We note that (i) given the exploratory nature of the approach, the results reported here should be replicated before any strong conclusions can be made, particularly as (ii)

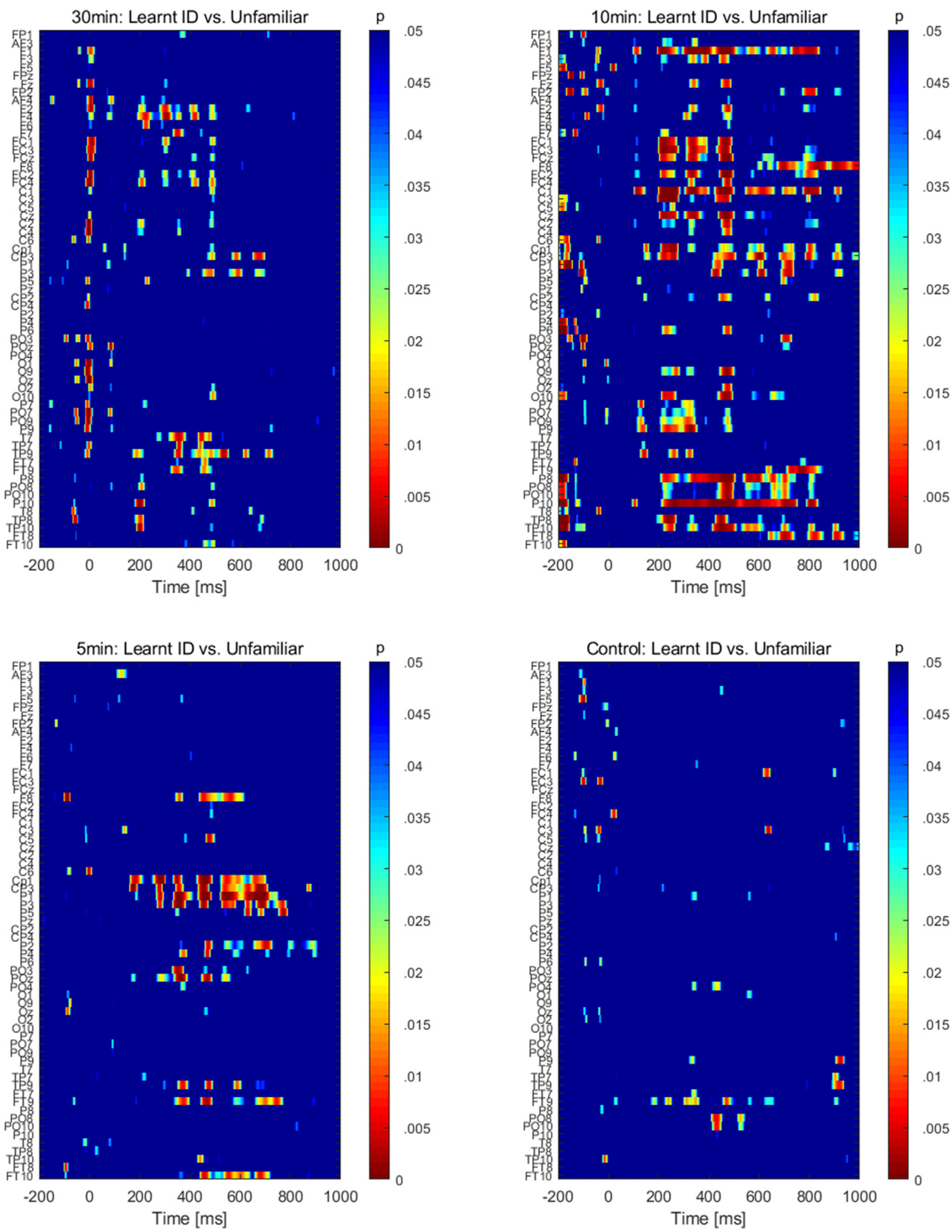

Fig. 3 – Mass univariate analyses for the within-group comparisons for each experiment.

none of these effects survived a correction for multiple comparisons using the False Discovery Rate procedure (Benjamini & Hochberg, 1995).

8. Discussion

The present series of experiments investigated how much time it takes to form a new image-independent face representation in real-life interactions with a new person. Using ERPs and the N250 familiarity effect as an index of visual familiarity, we examined whether robust, image-independent recognition could be established following a brief real-life encounter in response to novel, highly variable images of the newly learnt person. Significant learning effects were observed after a 30-min (Experiment 1) and a 10-min (Experiment 2) social encounter, while only trends were found in the N250 following a 5-min interaction (Experiment 3). These findings suggest that initial face representations build up within 5–10 min in everyday life encounters, and accordingly that we learn new faces very easily and quickly. Additionally, no difference between conditions was detected in a control experiment (Experiment 4), confirming that the observed effects in Experiments 1–3 indeed resulted from the social interaction before testing rather than from learning during the test sessions.

The current results substantially extend previous lab-based research (Andrews et al., 2017; Kaufmann et al., 2009; Tanaka et al., 2006; Zimmermann & Eimer, 2013) by demonstrating face learning under more naturalistic conditions. Importantly, while in the present study within-person variability during learning was restricted to the specific conditions of a single encounter (e.g. providing no changes in lighting, make-up, or hair), the images used at test were taken in widely different environmental conditions. Moreover, test images also depicted longer-term changes in the faces themselves, and on the basis of these two factors, it seems reasonable to conclude that test images contained substantially more variability relative to the learning session. Our finding of clear learning from limited variability under these testing conditions has important theoretical implications.

Theoretical models on face learning and recognition have formulated two different but not mutually exclusive views about the type of information stored in a newly established face representation. Burton et al. (2005) suggested that forming a new representation can be conceptualised as an averaging process across different instances. More specifically, the authors suggested that by averaging across different instances of the face, random variability (e.g. caused by different lighting, facial expressions, viewing angles etc.) would be filtered out, while information crucial to the identity of the face should be present in all instances, and should therefore emerge during the averaging process. In later work, Burton et al. (2016) have argued that variability should not be treated as noise but instead contains important identity-specific information. For instance, how a specific face appears to change with different light is not random but depends strongly on the individual shape and surface reflectance information. While the former average-based view construes face representations as abstract from any specific instance, the latter view implies that multiple instances or “snapshots” of a given facial identity are stored in a face representation, and that recognition occurs if a stimulus is similar to any of these instances.

The present results seem to be easier to integrate with an abstract rather than an instance-based account. As noted above, participants in the present study were exposed to the new face in only one specific situation, and yet recognised it from widely varying images. It therefore appears that participants had extracted information during the learning session that allowed recognition in very different circumstances. Crucially, as the newly learnt face had never been experienced in the conditions reflected in the test stimuli, participants could not possibly have an instance-based representation of these particular conditions. For instance, the participants could not have a snapshot of what the face looked like in lighting different from the learning situation because they had never seen the face in different lighting. Accordingly, we suggest that some form of invariant facial information was extracted in the learning session.

To our knowledge, this is the first study looking at the time course of real-life face learning. Our findings suggest that the establishment of robust, image-independent representations that allow for recognition from novel everyday images occurs during the first five to 10 min of a social interaction. Interestingly, the magnitude of the effects observed after 10 and 30 min was comparable suggesting that the variability experienced throughout the first 10 min is informative, while additional time from the same encounter does not provide detectable further benefit. It therefore appears that the variability experienced in the two conditions was very similar despite the difference in exposure duration. In other words, the different viewing angles, expressions etc. observed in the initial five to 10 min of exposure provided sufficient within-person variability to build an initial representation, while longer exposure to the person presumably repeated these views and did not contribute novel information to enhance learning. This suggestion is consistent with previous research which has highlighted enhanced learning following exposure to high as opposed to low variability while exposure duration was kept constant (Murphy, Ipser, Gaigg, & Cook, 2015; Ritchie & Burton, 2017).

It has to be noted that we only observed a trend in the earlier N250 time window (200–300 ms), in Experiment 1, which would have been significant had we decided to run one-sided tests before data analysis (which would have been possible, as we had clear a priori predictions about the direction of the effect). Moreover, the familiarity effect then became significant in the following late N250 time window (300–400 ms). In combination, this suggests to us that learning effects were present in the N250 time range in Experiment 1. Aa a potential explanation for the observed trend, we note that fewer participants ($N = 24$) were tested relative to the following experiments ($N = 34$). We started our study with assumptions about effect sizes and statistical power derived from previous experiments (Andrews et al., 2017), which we then adapted based on the results of Experiment 1. It thus seems plausible that the observed trend would have been significant with larger N (as in Experiments 2–4).

While reliable learning effects were detected following a single session of real-life familiarisation in the present study, the observed N250 effects were smaller than those elicited by well-known celebrities (Andrews et al., 2017; Gosling & Eimer, 2011), personally highly familiar faces (Wiese, Hobden, et al., 2022; Wiese, Tüttenberg, et al., 2019), and friends known for about two months (Popova & Wiese, 2022). Accordingly, while five to 10 min of social interaction appear sufficient for the initial establishment of face representations, more exposure to someone's idiosyncratic variability, presumably ideally spread out across several different encounters, is needed to strengthen these representations to the level of highly familiar faces. Recently, face recognition research has been shifting from a binary approach to familiarity, which compares familiar to unfamiliar faces, towards investigating how different levels of familiarity are represented in the brain (e.g. Ambrus et al., 2021; Andrews et al., 2017; Bobes et al., 2019; Li, Burton, Ambrus, & Kovács, 2022; Ramon & Gobbini, 2018; Wiese, Hobden, et al., 2022; Wiese, Tüttenberg, et al., 2019). The present results add to these findings and support theoretical accounts that conceptualise familiarity as a gradual rather than a bi-valent, dichotomous category (Kovács, 2020; Kramer et al., 2018).

As expected, brief exposure to a pre-experimentally unfamiliar person did not result in a clear SFE over and above the effect in the earlier time windows. While there was a significant difference between the newly learnt identity and the unfamiliar face in the SFE time window, the magnitude of the effect was substantially smaller than the SFE in response to highly familiar faces (Popova & Wiese, 2022; Wiese, Anderson, et al., 2022; Wiese, Hobden, et al., 2022; Wiese, Tüttenberg, et al., 2019). It appears that the N250 learning effects in the present study continue into the later time window but unlike previous studies with highly familiar identities, the difference between familiar and unfamiliar faces does not increase, indicating that no substantial additional processing is taking place following visual recognition. This is consistent with the finding that moderately familiar faces, such as university lecturers (Wiese, Tuettenberg, et al., 2019b) or celebrities picked by the experimenters (Wiese, Hobden, et al., 2022b) do not elicit a prominent SFE, and that the effect is only small in magnitude after approximately two months of personal familiarity (Popova & Wiese, 2022), i.e. after substantially more exposure than tested in any experiment of the present study. The present finding is also in line with the assumption that the SFE reflects the integration of visual with additional semantic and/or episodic knowledge. Although some identity-specific knowledge will be available following an initial brief interaction, it can arguably be only sparse, and may either be insufficient or insufficiently integrated with visual information to elicit the effect. Accordingly, substantially more prolonged and repeated exposure is needed to observe a clear SFE (Popova & Wiese, 2022).

Relatedly, our results can be interpreted in the context of a recent neuroscientific account (Kovács, 2020), which suggests that face and identity learning is accompanied by establishing representations not only in core face processing regions (such as the inferior occipital lobe and the lateral fusiform gyrus), but also in anterior temporal regions (reflecting semantic knowledge), the medial temporal lobe (for episodic memory), the temporo-parietal junction and the inferior parietal lobe (for personality traits and attitudes), as well as the insula and amygdala (for emotional responses). Critically, this account differentiates various categories of familiarisation, ranging from purely visual over contextual to closer personal familiarity. According to this system, face learning in the present study would arguably be categorised as at least contextual familiarisation, which is suggested to contain (some) semantic, episodic, and personality information about the to-be-learnt person. As noted above, however, familiarity effects in later time ranges associated with semantic and episodic processing were not prominent. Moreover, purely image-based, i.e. visual familiarisation has been shown to result in the same basic ERP effect—with more negative amplitudes for learnt relative to unfamiliar faces in the N250 time range (Andrews et al., 2017), arguing against the idea that familiarity as reflected in the N250 effect depends on a specific type of familiarisation (see also Wiese, Hobden, et al., 2022). In conclusion, it appears that a single, brief interaction with a new person is insufficient to establish contextual representations as suggested by Kovács (2020).

Our findings also seem to deviate to some extent from those of Ambrus et al. (2021), who reported that personal familiarisation resulted in stronger effects relative to purely perceptual learning. It should be noted, however, that, in addition to the different familiarisation procedures, the amount of exposure was substantially larger in the personal condition of Ambrus et al. (2021), which arguably reflects a quantitative rather than a qualitative difference for various types of familiarisation. Relatedly, while in our study familiarity effects were observed between 200 and 400 ms, Ambrus et al. (2021) found evidence for familiar face representations only after 400 ms. At present, it is unclear what underlies these differences between studies. One might speculate that the shorter learning time in the present study relative to Ambrus et al. (2021; 1 h on each of three consecutive days) explains the absence of a clear SFE. As noted above, however, even two months of familiarity are not sufficient to elicit the full effect (see Popova & Wiese, 2022), which renders this possibility unlikely to us. A further potentially important difference between studies lies in the substantial image repetition in Ambrus et al. (2021). Image repetition generally decreases ERP familiarity effects (see Wiese, Anderson, et al., 2022; Wiese, Tüttenberg, et al., 2019), and it may also reduce the sensitivity to detect such effects with other EEG-based methods.

As outlined in previous paragraphs, the present findings advance our current understanding of how face representations develop and show that a more ecologically valid experimental approach can be used to overcome limitations of purely laboratory-based face learning studies (e.g. Burton, 2013). It should be noted that this increased ecological validity is particularly reflected in the learning phase of our experiments as it consisted of a naturalistic conversation, including natural distances and face sizes for the learner. Images used at test contained natural within-person variability but were presumably presented at a smaller visual angle than during naturalistic interactions. Nevertheless, our findings have potential implications for more applied fields, and in particular, for research interested in the reliability of eyewitness testimony, as they contribute knowledge about the degree of familiarity necessary for reliable identification. However, any potential implications are limited by several important factors. While we reported clear familiarity effects immediately following a brief exposure, the time between initially meeting a person for the first time and the need to recognise this person later is usually much longer in applied scenarios. It is unclear how stable the familiarity effects observed in the present experiments are over time, and initial evidence suggests that newly learnt faces are likely forgotten within 24 h without additional training (Kramer, 2021).

As a limitation, we further note that it is unclear how much time our participants spent looking at the 'to-be-learnt' face. Confederates had to ensure that their faces were visible, but no specific instructions were given to the participants regarding the social encounter. We purposefully did not provide the participant/confederate pairs with a task that might have enforced focusing on the face to allow for a more naturalistic interaction. Therefore, it is not possible to decide on the basis of the present results whether the similar effects observed in the 10- and 30-min conditions were caused by a similar amount of time spent looking at the 'to-be-learnt' person or whether additional fixations in the longer condition did not provide additional useful information. Future studies are needed to clarify these questions.

In conclusion, the present study is the first to present electrophysiological evidence for the minimal time of exposure to a new person that allows the recognition of their face from novel images. We found evidence for image-independent face recognition after five-to 10-min interactions with a stranger, while 20 additional minutes of exposure did not result in learning effects over and above those observed after 10 min. These findings provide new insights into the time course of face learning and the initial formation of robust image-independent representations. Moreover, our results seem to support the formation of abstract rather than instance-based representations after an initial encounter with a new facial identity.

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Author contributions

Tsvetomila Popova: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration; Visualization; Roles/Writing - original draf; Writing – review & editing. Holger Wiese: Conceptualization; Formal analysis; Investigation; Methodology; Resources; Supervision; Roles/Writing - original draf; Writing – review & editing.

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Supplementary data

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