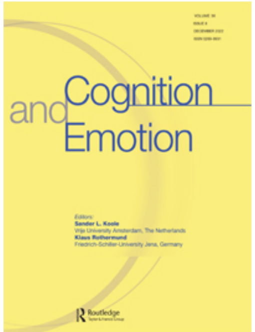

Cognition and Emotion

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/pcem20

Older adults get masked emotion priming for happy but not angry faces: evidence for a positivity effect in early perceptual processing of emotional signals

Simone Simonetti, Chris Davis & Jeesun Kim

To cite this article: Simone Simonetti, Chris Davis & Jeesun Kim (2022) Older adults get masked emotion priming for happy but not angry faces: evidence for a positivity effect in early perceptual processing of emotional signals, Cognition and Emotion, 36:8, 1576-1593, DOI: 10.1080/02699931.2022.2138269

To link to this article: https://doi.org/10.1080/02699931.2022.2138269

Published online: 27 Oct 2022.

COGNITION AND EMOTION
2022, VOL. 36, NO. 8, 1576–1593
https://doi.org/10.1080/02699931.2022.2138269

Routledge
Taylor & Francis Group

Older adults get masked emotion priming for happy but not angry faces: evidence for a positivity effect in early perceptual processing of emotional signals

Simone Simonetti[a,b], Chris Davis[a] and Jeesun Kim[a]

[a]The MARCS Institute for Brain, Behaviour and Development, Western Sydney University, Sydney, Australia; [b]Brain and Mind Centre, School of Psychology, University of Sydney, Sydney, Australia

ABSTRACT

In higher-level cognitive tasks, older compared to younger adults show a bias towards positive emotion information and away from negative information (a positivity effect). It is unclear whether this effect occurs in early perceptual processing. This issue is important for determining if the positivity effect is due to automatic rather than controlled processing. We tested this with older and younger adults on a positive/negative face emotion valence classification task using masked priming. Positive (happy) and negative (angry) face targets were preceded by masked repetition or valence primes with neutral face baselines. In Experiment 1, 30 younger and 30 older adults were tested with 50 ms primes. Younger adults showed repetition priming for both positive and negative targets. Older adults showed repetition priming for positive but not negative targets. Neither group showed valence priming. In Experiment 2, 30 older and 29 younger adults were tested with longer duration primes. Younger adults showed repetition priming for both positive and negative emotions, and no valence priming. Older adults only showed repetition and valence priming for positive targets. We proposed older adults' lack of angry face priming was due to an early attention orienting strategy favouring happy expressions at the expense of angry ones.

ARTICLE HISTORY
Received 6 October 2021
Revised 15 October 2022
Accepted 17 October 2022

KEYWORDS
Emotion recognition; emotional valence; aging; positivity effect; masked priming

The efficient processing of emotionally valenced signals such as facial expressions is important for social communication since such signals can provide clues about people's disposition and potential actions. Indeed, it has been proposed that the processing of visual signals is modulated by emotional valence, such that signals which are associated with a positive or negative valence are given a different priority and/or degree of processing (Johansson et al., 2004). For example, a well-known proposal is that our attentional system has evolved to facilitate the processing of threat related information (i.e. the anger superiority effect, Hansen & Hansen, 1988). Several theories, e.g. socioemotional selectivity theory (Carstensen, 2006), propose that a bias associated with processing negative or positive emotion shifts over the lifespan, with older adults exhibiting a preference for processing positive over negative material compared to younger adults, the so-called positivity effect. Given such a shift in old age to favour the processing of positive emotional stimuli, an important question concerns the processing stage at which this effect occurs. An early locus of this effect may indicate that the processing mechanisms that detect and monitor negative information become less effective with age; whereas a later stage locus would suggest more cognitive than perceptual mechanisms are at play.

CONTACT Chris Davis chris.davis@westernsydney.edu.au The MARCS Institute for Brain, Behaviour and Development, Western Sydney University, Locked Bag 1797, Penrith 2751, Australia
This article has been republished with minor changes. These changes do not impact the academic content of the article.

A recent review about the processing of negative and positively valenced face stimuli (Kauschke et al., 2019) divided studies into those that used tasks tapping early versus later stages of perceptual processing. Here, the former involved the detection of a face, such as the face in the crowd task (e.g. Hansen & Hansen, 1988), and the latter used tasks that required more explicit extraction of emotion information, such as identifying a facial expression from a photograph. For younger adults, the review identified many studies that showed an advantage in response time and sometimes accuracy for detecting a negative expression, anger, consistent with the proposal of the anger superiority effect (Hansen & Hansen, 1988). It also found many studies that showed an advantage for detecting a positive expression "happy" over a negative one "anger", demonstrating a positivity effect. The pattern of results was more uniform for studies that required the identification of emotion, where most studies found that the identification of a positive emotional expression was superior to a negative one. This was particularly the case for older adults. Indeed, it is well established that older adults are poor at identifying negative emotional expressions, Gonçalves et al. (2018). What is not currently clear is whether such a positivity effect in older adults is also apparent in early perceptual processing of emotionally valenced signals.

One of a few studies that have examined older adults' early processing of emotionally valenced expressions was conducted by Mather and Knight (2006). They used the face in a crowd search task in which participants were asked to indicate via a selective button press whether there was a discrepant face in a matrix of nine faces. They found that older adults were able to detect a schematic angry expression against a background of neutral ones faster than they could detect a happy expression. This result was interpreted as showing that the early processing of angry (negative) expression was intact in older adults. There is, however, a problem with the Mather and Knight (2006) study as it used schematic depictions of face emotions as employed by Öhman et al. (2001). Both Purcell and Stewart (2010) and Coelho et al. (2010) have shown the anger facilitation effect with these stimuli is largely driven by low-level visual artefacts. Moreover, in a recent review, Becker and Rheem (2020) have pointed out more general problems with the face in the crowd task even when photographs are used (as in Ruffman et al., 2009), e.g. whether an anger or happy facilitation effect is found depends on which face dataset is used (see also Savage et al., 2016, 2013).

Given the research background addressed above, the aim of the current study was to examine the early perceptual processing of positive and negative emotionally valenced face expressions. More specifically, we aimed to determine whether older adults are as efficient as younger adults in the early processing of these important social signals. To avoid the issues with the face in the crowd task, the current study used a different method, an implicit measure of stimulus processing based on a masked repetition priming paradigm (see Forster & Davis, 1984, for a general approach to the masked repetition priming paradigm). This method likely taps early visual information processing because it is based on priming a target response from a prime that is rapidly displayed immediately before the target, giving little time for elaborative processing. Moreover, the prime is forward and backward masked so that viewers are largely unaware of its presentation (thus avoiding response strategies based on explicit knowledge of prime and target relations). Masked repetition priming effects have been found for faces (e.g. Harry et al., 2012), are short-lived (lasting only a second or so, Forster & Davis, 1984) and are typically interpreted in terms of a saving in processing perceptual information relevant to task requirements (Kim & Davis, 2003). That is, when a decision on the target uses the analysis generated by the prime, it gets a "head-start" and so reduces overall response time, i.e. the work done in processing the prime is transferred to the processing of the target. Note, here, the work done on the prime is conceived in terms of perceptual evidence rather than at the level of generating a response (see the response interference paradigm below).

The above properties of masked repetition priming suggest that it is well-suited to assessing the early processing efficiently of emotion information conveyed by the masked prime. That is, a masked repetition priming effect, e.g. in which a prime face with happy expression facilitates responding to a happy target face in a positive or negative emotion classification task, would indicate that the emotion information from the prime had been processed quickly and efficiently. That is, if there are no problems with the initial processing of emotion information, then prime processing would result in a robust priming effect via transfer of this work to the analysis of the target. Little or no masked repetition priming would result if the emotion processing system was not able to generate emotion related information relevant to the target, i.e. the early analysis was not sufficiently well-developed for this work to be picked up by the target analysis.

We have used the term repetition priming to describe the facilitation of a target response in an emotion valence classification task, when the prime and target depict the same emotion (e.g. happy) and have suggested that this this type of priming be interpreted in terms of the processing savings that accrue to target processing from prime processing. This interpretation is based on measuring priming from repeated primes compared to unrelated ones, i.e. control primes that present information that is irrelevant to the decision to be made on the target (e.g. a neutral expression). There is another type of masked priming that has been extensively used in emotion research which uses a control prime that presents task incongruent information, e.g. in an emotion valence classification task, the control prime condition for a positive (happy) target face would be a negative (angry) one. In an extensive review of this literature, this method has been referred to as a response interference paradigm (Rohr & Wentura, 2021), and is thought to arise due to Stimulus-Response mappings such as action triggers (Kunde et al., 2003) or modified action triggers (Kiesel et al., 2006) that are set off by the presentation of the prime. We did not use this method as we were specifically interested in assessing the information processing of the prime, as measured by the head start it gives to the target compared to unrelated primes (see Gomez et al., 2013).

With the above considerations in hand, Experiment 1 was designed to assess priming in several key conditions. The first was to determine for older adults whether there is reduced repetition priming for negative (anger) compared to positive (happy) emotion targets. A second condition was to test repetition priming with younger adults on the same negative and positive emotion stimuli. Younger adults were tested to determine the relative balance of priming for positive and negative emotion targets in group where there is less evidence that the processing of negative emotion information is reduced. Finally, another prime condition was added to assess the locus at which priming occurs in the current paradigm. That is, using the response interference paradigm, Rohr et al. (2012) have shown that target responses can be influenced by emotional primes both in terms of the specific emotion displayed and the overall valence (positive versus negative). To examine whether valence priming occurs in the method we used, in addition to the repetition condition, we added a category priming condition. Here, category priming is where the prime and target refer to different emotion types, but they belong to the same task-defined category (i.e. negative or positive emotional valence). If priming occurs at the level of emotional valence, we expect to observe priming from same valence primes versus unrelated controls.

Experiment 1

Method

Participants

Thirty younger Adults ($M_{age} = 20$, range = 18-29, 26 females) and 30 older Adults ($M_{age} = 70$, range = 61-83, 17 females) participated in this study. Younger adults were university students and received course credit for their participation; the older adults, recruited from the local community, received monetary reimbursement. All participants reported to have normal or corrected to normal vision. Participants were screened for dementia using the Mini-Cog™ test (Borson et al., 2000) as the presence of dementia has been associated with poor emotion processing and may act as a confounding variable (Rosen et al., 2006). Both the older and younger adults scored within the normal range on the Mini-Cog™ test (where a score of at least 3 out of 5 points represents normal cognition) indicating no symptoms of dementia (Borson et al., 2000).

Note that with respect to statistical power, we based our participant number on experiment 2 in Rohr et al. (2012) that used a similar masked priming paradigm and tested 27 participants.

Stimuli

Thirty faces (15 female) were chosen from the Radboud database (Langner et al., 2010). For each face, two emotional expression variations (happy, angry) were chosen to be target images. Target stimuli showed the person turned slightly to the right, with their left cheek leading and their gaze directed to the front (a pose where emotion expressions are at their clearest, Lindell & Savill, 2010). For the prime stimuli, five emotional expression variations (happy, angry, surprise, disgust, neutral) from the same people were selected, prime faces showed the person in a full front-facing pose, i.e. a different pose to the target faces. For category priming, the expression of disgust and surprise were selected to be the category prime emotions for negative (angry) and positive (happy) target faces, respectively. The selection of disgust as a negative emotion and surprise as positive was based upon the valence dimension (Russell, 1980) for disgust (M = 1.99, SE = 0.169; where 1 = negative and 5 = positive) and surprise (M = 2.74, SD = 0.214), as given by the Support Material for Langner et al. (2010) for the frontal pose; and given the constraints on selection of expressions available in the Radboud database (surprise had the highest valence of the other emotions). An emotion expression that had a higher positive valence than surprise would have been ideal, however, issues concerning the selection of other positive facial expression beside happy are well known (Kauschke et al., 2019).

Faces were selected based on inter-rater agreement scores about the intended expression (see Langner et al., 2010, for inter-rater agreement scores). That is, faces that attracted the highest inter-rater agreement scores averaged across all emotion types were selected for this experiment. On average, the selected faces had similar inter-rater percent agreement scores, happy (*M* = 99%), surprise (*M* = 92%), angry (*M* = 93%), and neutral (*M* = 92%); the disgusted faces had a slightly lower average (*M* = 80%). A further four faces with three emotional expression variations (i.e. 2 female and 2 male faces x happy, angry, and neutral expression, n = 12) were selected from the database to be used as practice items.

In total, there were 222 images (12 practice images, 60 target faces, 150 prime faces). Images were cropped to include the face region and hairline. Images were then converted to gray-scale and the SHINE MATLAB toolbox was used to normalise intensity levels and spatial frequencies across all stimuli (Willenbockel et al., 2010). Target faces were resized to 6.56 × 8.68 cm and prime faces were resized to 4.37 × 5.79 cm as per Harry et al. (2012). The forward and backward masks were taken from the study by Harry et al. (2012). The forward mask consisted of an assortment of scrambled facial features (eye, noses, mouths) and the backward mask consisted of a blurred and scrambled face superimposed on a chequerboard (see Figure 1).

Procedure

Participants were tested individually in a sound attenuated booth. Participants were told that they would see a series of images, followed by a person expressing a positive or negative emotion; and that their task was to indicate which was expressed by pressing labelled buttons on a button box. Participants were instructed to respond as fast and as accurately as possible.

The DMDX program (Forster & Forster, 2003) was used to present stimuli and to collect responses via a two button response box (via a ComputerBoards PIO24 interface card). Participants were randomly assigned to one of two versions of the experimental list. That is, for half of participants, the right button corresponded with a "negative" response and the left button with a "positive" response.

Participants were first presented with eight practice trials followed by the experimental items. Altogether, there were 180 trials as each of the 60 target faces appeared 3 times accompanied by either a repeated prime emotion, i.e. $angry_p$-$angry_t$, $happy_p$-$happy_t$, a same positive or negative emotion category prime, i.e. $disgust_p$-$angry_t$, $surprise_p$-$happy_t$, or a neutral emotion prime (control), i.e. $neural_p$-$angry_t$, $neutral_p$-$happy_t$. Within each trial, participants were presented with a fixation cross (500 ms), followed by a forward mask (500 ms), a prime face (50 ms), a backward mask (33 ms), and a target face (700 ms), see Figure 1. The priming conditions were presented intermixed and item order was randomised for each participant. Response time and error rates were recorded. Participants were given a break every 18 trials to avoid fatigue effects. At the end of the experiment, participants were debriefed regarding the purpose of the study.

Results

For older adults, error rates were low, e.g. positive targets, M = 3.8%, SD = 0.12; negative targets, M = 4.4%, SD = 1.2. There were no significant effects of Target type or Prime type for the repeated and category priming conditions. For younger adults, positive targets, M = 5.19, SD = 0.22; negative targets, M = 5.15, SD = 0.22. There was no significant effect of Target or Prime type for the repeated and category priming conditions.

Prior to analysing the response time data, lower and upper response time cut-offs were applied to each participant's response time data (lower cut-off = 150 ms; upper cut-off = 1500 ms). A winsorisation procedure was then used to curtail the influence of outlying response times. In this procedure, response times that were +/- 3 SD from each participant's mean response time were brought back to a prespecified boundary (see Dixon & Yuen, 1974). Across the

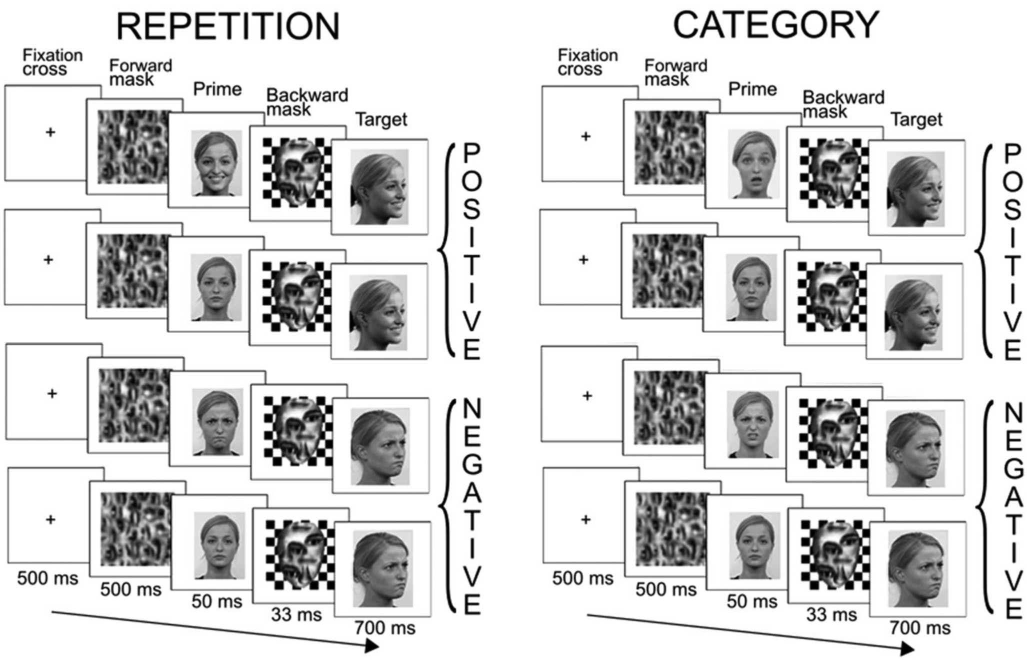

Figure 1. The sequence of frames (and timing) presented on each trial for the positive and negative valenced targets. The repetition conditions (repeated and neutral primes) are shown in the left panel; the category conditions (same valence and neutral primes) in the right one.

30 younger adults, winsorisation was applied on average 2.30 times per participant and cut-offs were applied on average 0.03 times per participant. For older adults, winsorisation was applied on average 2.50 times and cut-offs were applied on average 0.10 times. The data from one older adult was excluded from further analysis due to her responses being a clear outlier, i.e. average response time more than 300 ms slower than the other participant's mean (> 900 ms), and her average error rate three times higher than the other participant's mean (> 14%). The final sample consisted of 29 older adults (M_{age} = 69, range = 61-83, 16 females).

The analysis strategy was to examine the evidence for repetition priming (repeated versus neutral primes) for the two emotion types separately for the older and younger adult groups. This strategy was based on the primary interest of investigating older adult processing given the practical resource constraint that testing a between-group variable (i.e. age group) would require very large participant numbers, assuming a typical effect size of d = 0.4 and wanting 80% power (see Brysbaert, 2019). The aim of the analysis was to determine: 1. Do older adults get priming from angry primes? 2. Do they get priming from happy primes? 3. Is there a difference in the size of priming for the two prime types? The same analyses were then conducted for younger adults. Following this, these analyses were carried out on the category priming data, i.e. comparing the Same valence versus neutral conditions. The results and data analysis are presented below.

Repetition priming: repeated versus neutral control primes

Mean correct response times for the older and younger adults as a function of Target type (positive, negative) and Prime type (repeated, neutral) are presented in Figure 2. As can be seen from the figure, the pattern of correct classification response times is consistent with the proposition that older adults have a bias against processing negative (angry) expressions, i.e. the only condition where there appeared to be no priming effect was for older adults with the negative (Angry) targets.

Two linear mixed model analyses were conducted; one for the older adult response data and one for the younger adult data. Both models included random intercepts for both participants and items; however, including random slopes resulted in singular models and so reduced models were used (see Bates et al., 2015; Matuschek et al., 2017, on fitting overparameterized models). The models used the afex r package

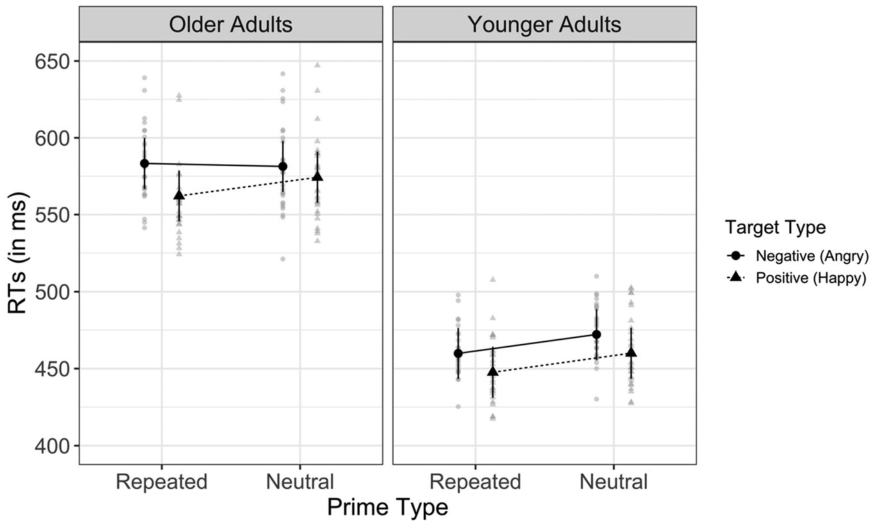

Figure 2. Mean correct response times to the two emotion targets (negative – Angry, positive – Happy) for the older and younger adults as a function of Prime type (Repeated, Neutral; i.e. repetition priming). Note: In this and subsequent figures, black bars represent 95% confidence intervals (model-based); the grey dots show item data.

(Singmann et al., 2016) and tested prime type (repeated vs. neutral) and target type (positive vs. negative) [model: mixed(rt ∼ prime_type*target + (1|subj) + (1|targetN))].

Older adults. The results for the analysis of the older adult response time data are shown in Table 1. The performance package (option: check_model) from the easystats r package (Lüdecke et al., 2022;) was used for assumption checks of the fitted models, e.g. homogeneity of variance; collinearity; the normality of the residuals, and normality of the random effects, which all reported models met.

As can be seen in Table 1, the effect of Prime type was not significant; whereas the effect of Target type was significant, as was the interaction between Prime and Target type. This significant interaction was examined in a set of planned comparisons that were conducted using the emmeans package (1.5.1; Lenth et al., 2019) and adjusted for multiple comparisons using a multivariate t distribution approach.

Two planned comparisons were conducted to assess priming for the positive and negative targets. The first comparison indicated that there was a significant priming effect for the positive targets (Happy). That is, targets in the Repeated condition (M = 561 ms, SE = 13.7, 95% CI = 547–601 ms) were responded to significantly faster than those in the Neutral condition (M = 574 ms, SE = 13.8, 95% CI = 534 –588 ms), effect estimate = 12.25 ms, (SE = 4.92), Z-ratio = 2.487, *p* = 0.0129.

The other planned comparison indicated that the priming effect for the negative (Angry) targets was not statistically significant, with mean response times in the Repeated condition (M = 583 ms, SE = 13.8, 95% CI = 554–608 ms) slightly longer than in the Neutral one (M = 581 ms, SE = 13.8, 95% CI = 556–610 ms), effect estimate = −1.83 ms, (SE = 4.95), Z-ratio = −0.368, *p* = 0.7126.

Younger adults. The results of the analysis of the younger adult response time data are shown in Table 2. As can be seen in the table, the effect of Prime type was significant, as was the effect of Target type; there was no significant interaction between Prime and Target type.

Table 1. Summary of the analysis of the linear mixed model of correct response times (ms) for older adults as a function of Prime type (Repeated, Neutral; i.e. repetition priming) and Target type (positive, negative) and their interaction.

Effect		df	F-ratio	*p*-value
Prime type		1, 3276.04	2.23	.136
Target type		1, 56.95	6.58	.013
Prime type * Target type	Type	1, 3276.05	4.06	.044

Table 2. Summary of the analysis of the linear mixed model of correct response times (ms) for younger adults as a function of Prime type (Repeated, Neutral; i.e. repetition priming) and Target type (positive, negative) and their interaction.

Effect		df	F-ratio	*p*-value
Prime type		1, 3335.52	19.20	<.001
Target type		1, 57.28	8.61	.005
Prime type * Target type	Type	1, 3335.41	0.00	. 947

Once again, a set of planned comparisons was conducted to examine the priming effect for the positive and negative target items. There was a significant repetition priming effect for the Positive targets (Happy), with responses in the Repeated condition (M = 449 ms, SE = 6.79, 95% CI = 435–462 ms) significantly faster than those in the Neutral condition (M = 461 MS, SE = 6.79, 448–474 ms), effect estimate = 12.1 ms, SE = 3.95, Z-ratio = 3.054, *p* = 0.0023.

There was also a significant priming effect for the negative targets (Angry); that is responses in the Repeated condition (M = 461 ms, SE = 6.79, 95% CI = 448–474 ms) were significantly faster than those in the Neutral condition (M = 473 ms, SE = 6.79, 95% CI = 460–487 ms), effect estimate = 12.4 ms, SE = 3.95, Z-ration = 3.144, *p* = 0.0017.

Category priming: same valence versus neutral control primes

The analysis of the category priming results was the same as for repetition priming, i.e. two linear mixed model analyses were conducted, one for older and one for younger adult response data. For consistency with the repetition priming analysis, we used the same model contrasts [Model: mixed (rt ~ prime_type * target + (1 | subj) + (1 | targetN))]. The mean correct target response times for both the older adult and the younger adult participants as a function of prime type (Same valence versus Neutral) are shown in Figure 3.

Older adults. The results of the analyses for the older adult data are shown in Table 3. As can be seen, there was no significant effect of Prime type, nor Target type, and the interaction between Prime and Target type was also not significant.

Two planned comparisons were conducted to assess the priming effect for the positive and negative targets. The category priming effect for the positive targets (Happy) was not significant, i.e. response times in the Same valence condition (M = 571 ms, SE = 13.3, 95% CI = 544–598 ms) did not significantly differ from those in the Neutral condition (M = 574 ms, SE = 13.3, 95% CI = 547–601 ms), effect estimate = 3.17 ms, SE = 4.84, Z-ratio = 0.654, *p* = 0.5130.

The category priming effect for the negative targets (Angry) was also not significant. That is, targets preceded by Same valence primes (M = 581 ms, SE = 13.3, 95% CI = 553–608 ms) were not significantly faster than those preceded Neutral ones (M = 581 ms, SE = 13.3, 95% CI = 554–608), effect estimate = 0.646 ms, SE = 4.86, Z-ratio = 0.133, *p* = 0.8943.

Younger adults. The results of the analyses for the younger adult category priming data are shown in

Table 3. Analysis summary of the linear mixed model of correct response times (ms) for older adults as a function of Target type (positive, negative) and Prime type (Same valence, Neutral; i.e. category priming) and their interaction.

Effect	df	F-ratio	*p*-value
Prime type	1, 3268	0.31	.578
Target type	1, 57.28	1.95	.168
Prime type * Target type Type	1, 3268	0.14	.713

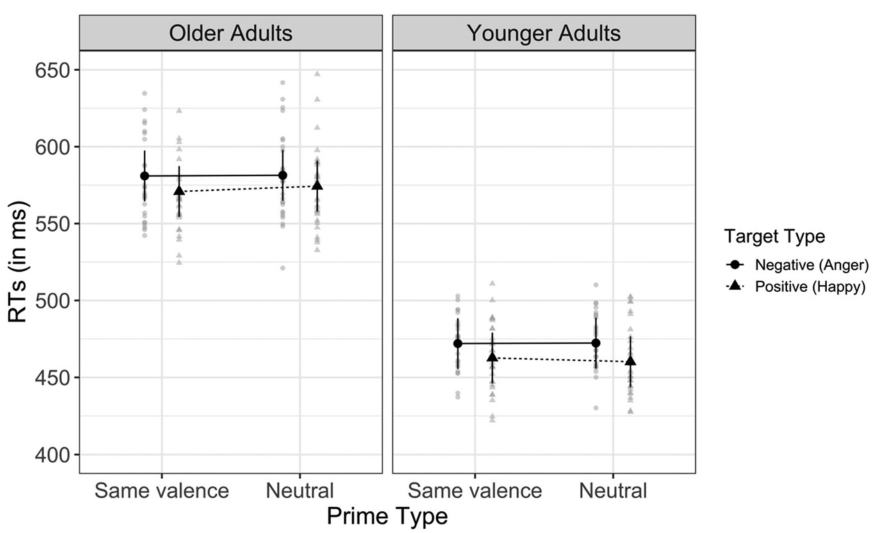

Figure 3. Mean correct response times to the two emotion targets (positive, negative) for the older adults as a function of Prime type (Same valence, Neutral; i.e. category priming).

Table 4. Analysis summary of the linear mixed model of correct response times (ms) for younger adults as a function of Target type (positive, negative) and Prime type (Same valence, Neutral; i.e. category priming) and their interaction.

Effect		df	F-ratio	*p*-value
Prime type		1, 3314	0.08	.776
Target type		1, 57.94	5.56	.022
Prime type * Target type	Type	1, 3314	0.40	.527

Table 4. As can be seen, the effect of Prime type was not significant. There was a significant effect of Target type, and the interaction between Prime and target type was not significant.

Two planned contrasts evaluated the priming effects for the positive and negative targets, respectively. The first indicated that there was no significant category priming for the positive targets (Happy); response times to targets in the Same valence condition (M = 464 ms, SE = 6.83, 95% CI = 450–477 ms) did not differ significantly from those in the Neutral condition (M = 461 ms, SE = 6.82, 95% CI = 447–475 ms), effect estimate = −2.65 ms, SE = 4.08, Z-ratio = −0.648, $p = 0.5168$.

The category priming effect for the negative targets (Angry) was also not significant, i.e. response times to targets in the Same valence condition (M = 472 ms, SE = 6.82, 95% CI = 459–486 ms) were not significantly different from those to targets in the Neutral condition (M = 473 ms, SE = 6.82, 95% CI = 460–487 ms), effect estimate = 1.00 ms, SE = 4.08, Z-ratio = 0.246, $p = 0.8056$.

Discussion

The masked repetition priming results were clear cut, older adults showed priming from happy faces but no priming from angry faces. Younger adults showed priming from both happy and angry faces and the size of these priming effects were not significantly different. These results suggest that older adults were able to extract sufficient emotion relevant information from happy prime faces to influence target classification but could not do so from angry prime faces. This finding is at odds with those from emotion detection studies that suggest that the early processing of angry expressions occurs in older adults (e.g. Hahn et al., 2006; Mather & Knight, 2006; Ruffman et al., 2009). The finding that older (and younger) adults also classified happy expressions as positive faster than they did angry faces as negative is also inconsistent with the proposal that there is a processing advantage for angry expressions (Hansen & Hansen, 1988).

A straightforward explanation for why older adults did not show repetition priming for angry expressions is that they needed more time to extract the relevant emotion information from the angry face primes. That is, given that a masked priming effect is generated when sufficient work has been carried out on the prime stimulus to enable that work to be transferred to target processing, then priming will be constrained by whether the prime has been processed sufficiently for this processing to be transferred. In this regard, there is evidence that older adults require more visual information to achieve emotion recognition performance similar to younger adults. For example, Smith et al. (2018) used a bubble paradigm, in which only facial information behind randomly positioned circular apertures was presented, and found that older adults required more spatial information (approximately 15% more bubbles) to achieve recognition levels similar to the young adults.

It is, however, unclear how this difference between older and younger adults in the amount of emotion information required for explicit recognition would translate to a difference in the time-course of emotion processing. Moreover, to explain why angry primes did not produce a priming effect, whereas happy primes did, it would need to be the case that angry emotion information takes longer to extract than happy information. Smith et al. (2018) did not present data on this comparison. Note here, that Becker and Srinivasan (2014) have argued that processing happy faces may be prioritised in early information processing because a happy expression employs visual features that are especially salient. However, if this were the case, it would be expected that the younger adults should have shown a larger priming effect for happy faces than angry ones, and this was not the case. Given that a happy expression is more salient than an angry one, larger priming from happy vs. angry faces could occur at longer prime-target stimulus onset asynchronies (SOA) due to happy having fewer competitors.

In sum, a simple explanation for why older adults did not show repetition priming for angry faces is that they did not have sufficient time to process prime information so that it could influence the target. If the lack of priming from angry expressions was due to insufficient time to process the prime, then increasing the prime-target SOA should increase the chance of older adult's showing priming for this emotional expression. Finding that increasing prime-target SOA did not result in priming for angry expression would indicate the need for a more complex reason why the early visual processing of angry expressions by older adults is weak.

The other main result from the first experiment was that there was no category priming, either for the younger or older adults. This result may seem surprising given that priming for congruently valenced stimuli is routine in the evaluative priming literature (see Rohr & Wentura, 2021). However, as pointed out above, such priming is observed when measured against an incongruent response baseline; and the underlying mechanism is thought to be that a prime-activated response competes with the response activated by target processing (Rohr & Wentura, 2021). This competition between an implicit response generated by prime and the target response would not occur in the current paradigm as it used an unrelated baseline. It is not clear from the evaluative priming literature whether the congruency between primes and targets per se would be sufficient to generate a priming effect against an unrelated baseline. If this were possible, it should be the case that extending the prime-target SOA will increase the chance of observing such a priming effect, as this would allow for more extensive prime processing and thus greater potential to generate an implicit response congruent with the one to be made on the target. The effect of increasing prime duration on category priming will also be tested in Experiment 2.

Experiment 2

Experiment 2 investigated whether older adults would show repetition priming from negative face primes that were presented for longer than those of Experiment 1 (50 ms). Three longer prime durations were used (i.e. 58, 67, and 83 ms); otherwise, the experimental (priming) conditions were the same as in Experiment 1. If the lack of repetition priming for angry expressions was due solely to older participants needing more time to process the facial features associated with anger, then increasing the prime duration should increase the chance of observing priming. For positive (happy) primes and targets, for which older adults showed priming, increasing prime duration may result in an even larger priming effect given the proposal of Forster (1999) that an increase in prime duration should result in an increase in priming. Younger participants were also tested to determine the effect of increasing prime durations on priming for younger adults. Since younger adults showed repetition priming for both negative and positive targets, increasing prime duration should result in an increase in priming for both; with (positive) happy expressions possibly attracting a larger priming effect as these are especially vivid (Becker & Srinivasan, 2014) and may thus have fewer perceptual competitors.

Method

Participants

Thirty older adults ($M_{age} = 72$, range = 61–83, 16 females), recruited from the local community, participated for monetary reimbursement. Older adults were screened for dementia using the Mini-Cog^{TM} test; they scored within the normal range. Twenty-nine younger adults ($M_{age} = 30$, range = 23–38, 17 females), recruited from the community using a "snowball" method, also participated and scored within the normal range on the Mini-Cog^{TM} test.

Stimuli

The same face stimuli as used in Experiment 1 were used in the current experiment.

Procedure

The procedure from the previous experiment remained largely the same as Experiment 1 except that the presentation duration of the prime stimuli was manipulated. That is, prime stimuli were presented for three different durations: 58, 67, and 83 ms; items with different display durations were presented intermixed, i.e. not blocked. This resulted in a total of 540 trials consisting of 30 faces, 2 target emotion types, 3 prime emotion types, and 3 prime durations. The priming conditions were presented intermixed and item order was randomised for each participant.

Results & discussion

As in Experiment 1, the error rate was low, e.g. younger adults, mean errors for the negative targets = 4.59%; SD = 0.21 and for the positive targets, M = 4.15, SD = 0.20. There was no significant effect of Target type or Prime type for either the repeated or category priming conditions. The same was the case for the older adults, e.g. mean errors for negative targets M = 3.86; SD = 0.19 and for the positive targets, M = 3.84, SD = 0.19. There was no significant effect of Target type or Prime type for either the repeated or category priming conditions.

As per Experiment 1, lower and upper response time cut-offs were applied to each participant's response time data (lower cut-off = 150 ms; upper cut-off = 1500 ms) and a winsorisation procedure was used. Across the 30 older adults, winsorisation was applied on average 6.83 times and cut-offs were applied on average 0.03 times. For the Younger adults, winsorisation was not applied and cut-offs were applied on average 0.01 times. The data were analysed and the results presented as below.

Repetition priming: repeated and neutral control primes

Mean correct response times for the older adults (top panel) and younger adults (bottom panel) as a function of Target type (positive, negative), Prime type (Repeated, Neutral) and Prime duration (58, 67 and 83 ms) are shown in Figure 4.

As in Experiment 1, two linear mixed models were conducted to analyse the response time data; one for the older and one for the younger adult response data. The effects of Target type (negative – Angry vs. positive – Happy) and prime type (repetition vs. neutral prime) and Prime duration were analysed with participants and items as random factors [model: mixed(rt ~ Target type * Prime type * Prime duration) + (1 | Participant) + (1 | Item)].

Older adults. The results of the analyses of the older adult response times are shown in Table 5.

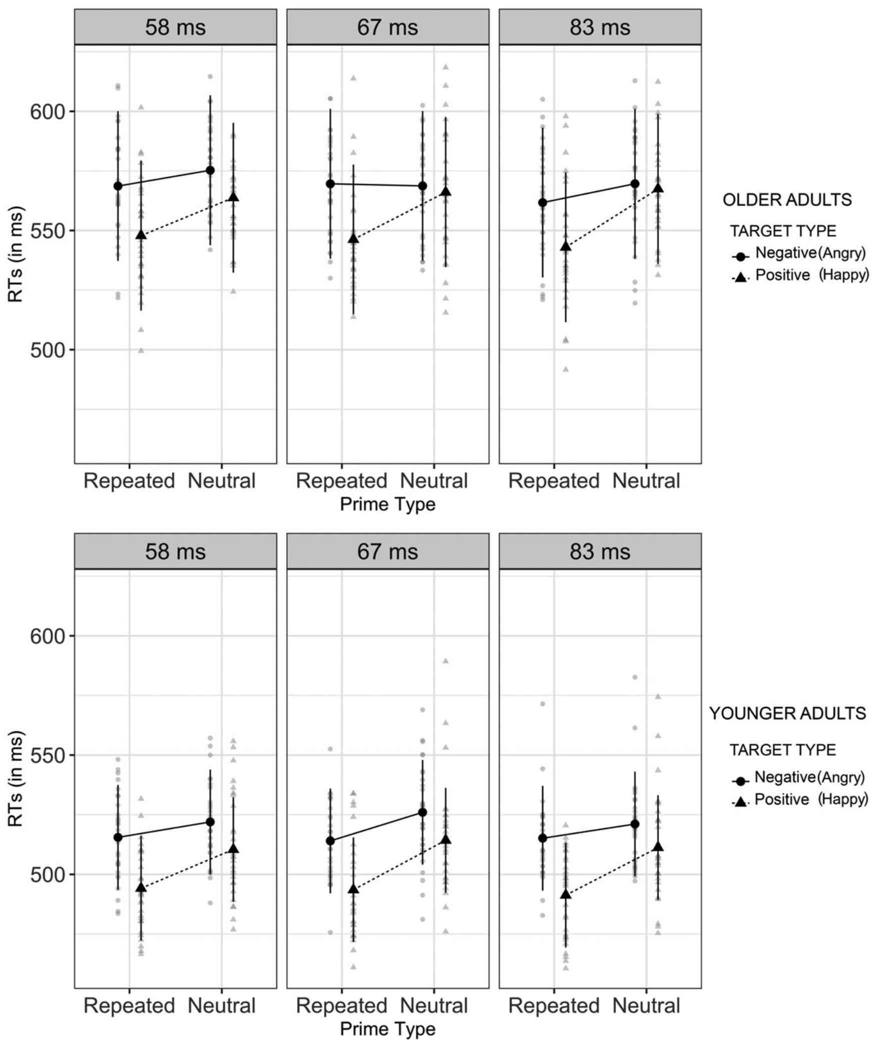

Figure 4. Mean response times for older adults (top panel) and younger adults (bottom panel) as a function of Target type (positive, negative), Prime type (repeated, neutral; i.e. repetition priming) and Prime duration (58, 67 and 83 ms).

Table 5. Summary of the analysis of the linear mixed model of correct response times (ms) for older adults as a function of Prime type (Repeated, Neutral; i.e. repetition priming), Target type (positive, negative) and Prime duration and their interaction.

Effect	df	F-ratio	*p*-value
Prime type	1,10308	37.97	<.0001
Target type	1,10309	43.67	<.0001
Prime duration	2,10308	1.01	0.364
Prime type*Target type	1,10307	15.11	<.0001
Prime type*Prime duration	2.10308	1.01	.364
Target type*Prime duration	2,10308	0.68	.505
Prime type*Target*Prime duration	2,10308	0.70	.496

In summary, there was a significant effect of Prime type, with repeated primes (556 ms) attracting faster response than control primes (569 ms). There was also a significant effect of Target type with responses to positive (Happy) targets (M = 556 ms) faster than negative (Angry) target faces (M = 569 ms). There was no significant effect of Prime duration. There was a significant interaction between Prime type and Target type. None of the interactions with Prime duration were significant.

To examine the significant interaction between Prime type and Target type, planned comparisons were conducted for the positive (Happy) and negative (Angry) targets using the emmeans package. For the positive (Happy) targets, there was a significant priming effect, such that targets preceded by repeated primes (M = 546 ms) were responded to faster than those preceded by neutral primes (M = 566 ms), effect estimate = 20.07 ms, SE = 2.82, Z-ratio = 7.11, p <.0001. For negative (Angry) targets, there was no significant effect of priming, responses in the repeated prime condition (M = 567 ms) did not significantly differ from those in the neutral condition (M = 571), effect estimate = 4.55 ms, SE = 2.83, Z-ratio = 1.61, *p* = 0.1077.

Younger adults. The results of the analyses for the younger adult response times are shown in Table 6.

In summary, there was a significant effect of Prime type, with repeated primes (503 ms) attracting faster response than control primes (517 ms). There was also a significant effect of Target type with responses to positive (Happy) targets (M = 503 ms) faster than negative (Angry) target faces (M = 519 ms). There was no significant effect of Prime duration. There was a significant interaction between Target type and Prime type. None of the interactions with Prime duration were significant. To examine the significant interaction between Target type and Prime type, planned comparisons were conducted for the positive (Happy) and negative (Angry) targets using the emmeans package.

For the positive (Happy) targets, there was a significant priming effect, such that targets preceded by repeated primes (M = 493 ms) were responded to faster than those preceded by neutral primes (M = 512 ms), effect estimate = 18.98 ms, SE = 2.51, Z-ratio = 7.56, p <.0001. For negative (Angry) targets, there was a significant effect of priming, responses in the repeated prime condition (M = 515 ms) were significantly differed from those in the neutral condition (M = 523 ms), effect estimate = 8.13 ms, SE = 2.51, Z-ratio = 3.24, *p* = 0.0012.

Category priming: same valence versus neutral control primes

Mean correct response times for category priming (Same valence vs. Neutral) as a function of Age group (older adults, younger adults), Target type (positive, negative) and Prime duration (58, 67 and 83 ms) are presented in Figure 5.

The category priming results were analysed with two linear mixed models; one for the older adult response time data and one for the younger adult data [both models: mixed(rt ~ Target type * Prime type * Prime duration) + (1 | Participant) + (1 | Item)].

Older adults. The results of the analyses of the older adult response times the same valence primes and targets versus the neutral control are shown in Table 7.

In summary, there was a significant effect of Target type, with responses to positive (Happy) targets (M = 562 ms) significantly faster than those to negative (Angry) targets (M = 574 ms). The effect of Prime type was not significant, i.e. responses to Same valence primes (M = 567 ms) were not significantly different from control primes (M = 569 ms). There was no effect of Prime duration. There was a significant interaction between Target type and Prime type. None of the interactions with Prime duration were significant.

Table 6. Summary of the analysis of the linear mixed model of correct response times (ms) for younger adults as a function of Prime type (repeated, neutral; i.e. repetition priming), Target type (positive, negative) and Prime duration and their interaction.

Effect	df	F-ratio	*p*-value
Prime type	1,10308	58.21	<.0001
Target type	1,10309	85.90	<.0001
Prime duration	2,10308	0.56	0.569
Prime type*Target type	1,10307	9.32	0.002
Prime type*Prime duration	2.10308	0.69	0.5
Target type*Prime duration	2,10308	0.02	0.984
Prime type*Target*Prime duration	2,10308	0.20	0.816

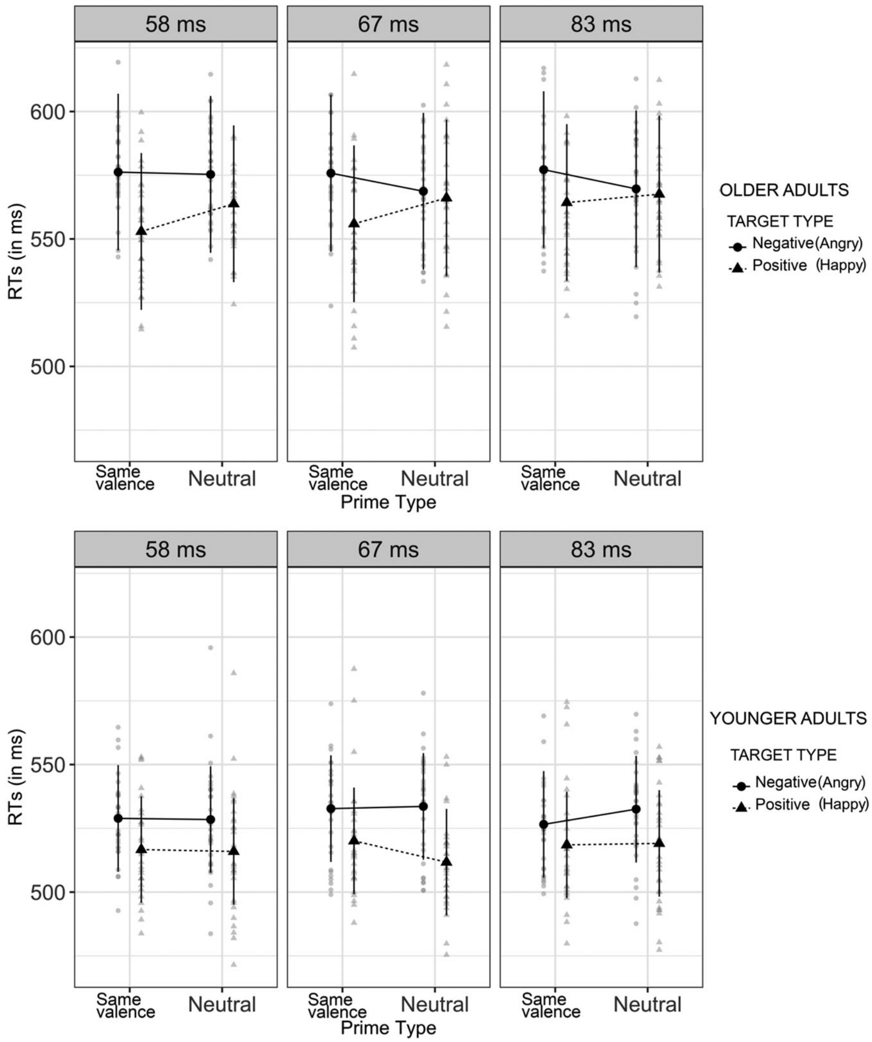

Figure 5. Mean response times for older adults (top panel) and younger adults (bottom panel) to the two emotion targets (positive, negative) as a function of Prime type (Same valence, Neutral; i.e. category priming) and Prime duration.

Given the significant interaction between Target type and Prime type, planned comparisons were conducted for the positive and negative targets using the emmeans r package. There was a significant priming effect for positive (Happy) targets, with targets preceded by Same valence primes (M = 558 ms) responded to faster than those preceded by Neutral primes (M = 566 ms), effect estimate = 8.09 ms, SE = 2.77, Z-ratio = 2.977, $p = 0.003$. For negative (Angry) targets, the priming effect was in the negative priming direction (i.e. interference) with targets preceded by Same valence primes (M = 576 ms) slower than those preceded by Neutral primes (M = 571 ms), this difference was not secure, effect estimate = −5.18 ms, SE = 2.77, z-score = 1.829, $p = 0.067$.

Table 7. Summary of the analysis of the linear mixed model of correct response times (ms) for older adults as a function of Prime type (Same valence, Neutral; i.e. category priming), Target type (positive, negative) and Prime duration and their interaction.

Effect	df	F-ratio	*p*-value
Prime type	1,10305	0.55	0.457
Target type	1,10305	37.89	<0.0001
Prime duration	2,10304	0.93	0.394
Prime type*Target type	1,10305	11.47	<.001
Prime type*Prime duration	2.10305	1.096	0.334
Target type*Prime duration	2,10305	2.172	0.114
Prime type*Target*Prime duration	2,10305	0.261	0.770

Younger adults. The results of the analyses of the younger adult response times are shown in Table 8.

There was a significant effect of Target type, with responses to positive (Happy) targets (M = 517 ms) significantly faster than those to negative (Angry)

Table 8. Summary of the analysis of the linear mixed model of correct response times (ms) for younger adults as a function of Prime type (Same valence, Neutral; i.e. category priming), Target type (positive, negative) and Prime duration and their interaction.

Effect	df	F-ratio	*p*-value
Prime type	1,10129	0.05	0.8320
Target type	1,10130	63.24	<.0001
Prime duration	2,10129	0.55	0.5762
Prime type*Target type	1,10129	2.15	0.1425
Prime type*Prime duration	2.10129	1.43	0.2373
Target type*Prime duration	2,10129	1.34	0.2619
Prime type*Target*Prime duration	2,10129	0.59	0.5566

targets (M = 530 ms). The effect of Prime type was not significant, i.e. responses to targets preceded by Same valence primes (M = 524 ms) were not significantly different from those preceded by control primes (M = 524 ms). There was no effect of Prime duration. The interaction between Target type and Prime type was not significant and none of the interactions with Prime duration were significant.

Planned comparisons were conducted to assess the category priming effects using the emmeans package. The priming effect for positive (Happy) targets was in the negative priming direction; targets preceded by Same valence primes (M = 518 ms) were responded to slightly slower than those preceded by Neutral primes (M = 516 ms), but this difference was not significant, effect estimate = −2.12 ms, SE = 2.39, Z-ratio = 1.188, $p = 0.2347$. For Angry targets, the priming effect was in the positive priming direction with targets preceded by Same valence primes (M = 529 ms) faster than those preceded by Neutral primes (M = 532 ms), this difference was not significant, effect estimate = 2.84, SE = 2.39, Z-ratio = 0.886, $p = 0.3756$.

In sum, for repetition priming, older adults showed robust priming for positive (Happy) targets but no significant priming effect for negative (Angry) targets. These results consolidate those of Experiment 1 and suggest that the failure to see evidence of negative prime processing by older adults was due to more than simply the delayed processing of negative primes. There was no significant interaction between repetition priming and prime duration. One reason why the different prime durations did not produce a clear effect on the size of priming may be due to the different duration trials being intermixed. That is, Schmidt et al. (2011) suggest that although in general it is advisable to intermix the experimental conditions in priming experiments, this should be avoided when prime-target SOA is studied. The reason they give is that participants may adjust their response criteria to the longest SOA to avoid response errors and this delay can obscure priming effects.

Younger adults showed significant repetition priming for both the positive and negative emotion targets, with priming for the positive emotion targets significantly larger than that for the negative ones. This interaction suggests that happy primes received more processing than angry ones and thus the positive targets received a greater processing saving from the analysis of the prime. This interaction did not occur in Experiment 1, that had a shorter prime duration. One possibility is that happy expressions attract extra priming because the key facial feature of happy expressions, the smile, is unique and salient (Calvo & Nummenmaa, 2008; Calvo et al., 2012), i.e. there are fewer competitors to curtail evidence for this analysis. The interaction effect between prime duration and priming was not significant, as mentioned above, possibly due to the intermixing of the various priming duration trials.

For category priming, older adults showed a significant priming effect for the positive targets and a tendency for an interference effect for the negative (Angry) ones; indeed, the negative priming effect was significant when the two longer prime durations were considered, ($p = .028$). There was a significant interaction between target type and prime type. There was no masked category priming for younger adults. This indicates that the same valence primes did not trigger an implicit valence response of sufficient strength to influence the response to the target.

General discussion

The present study investigated the extent of early processing of negative and positive facial expressions of emotion by older and younger adults. To assess early-stage processing of these stimuli we used a masked priming procedure in which a target to be classified as having a positive or negative emotional expression was preceded by a masked emotion prime stimulus. We examined both repetition and category priming using positive (Happy) and negative (Angry) target faces (with neutral prime faces as a baseline). The first experiment had a prime duration (and prime-target stimulus onset asynchrony) of 50 ms; Experiment two had three longer prime durations (58, 67, 83 ms). Below, we will first discuss the repetition priming and category priming results for older and then for the younger adults.

Repetition priming for older adults

It is clear the repetition priming results do not support the idea that a low-level perceptual mechanism initially prioritises negative (threat) information either for older or younger adults. The finding that older adults showed repetition priming from positive happy faces is consistent with the idea of a happy face advantage (Becker & Rheem, 2020). However, a happy face advantage does not explain why there was no priming effect from angry faces for older adults, or why younger adults did not show a larger happy compared to angry priming effect (in Experiment 1).

Interestingly, the older adult repetition priming results fit with the broad description of the positivity effect, i.e. heightened processing of positive and reduced processing of negative emotion information (Reed & Carstensen, 2012). However, as it stands, the positivity effect and the way it typically has been explained seem inappropriate for interpreting masked priming effects. This is because the standard theoretical underpinning of the positivity effect is the socioemotional selectivity theory (SST); a broad theory concerning how a person's conception of future time horizons plays an important role in shifts of motivation (Carstensen, 2006). That is, the SST explains older adults' preference for positive over negative information in terms of late-stage controlled attentional processes not automatic ones (Reed & Carstensen, 2012). As such, the SST appears to have little to say about mechanisms involved in the initial stages of perceptual processing that are likely tapping by masked repetition priming.

There is an alternative model of the positivity effect that may be more suitable for incorporating masked priming effects. The Dynamic integration theory (DIT) is a lifespan emotional development theory that like the SST considers changes in older age (Labouvie-Vief, 2003). However, whereas the SST proposes that cognitive control is necessary for the positivity effect, the DIT proposes that the prioritisation of positive experiences by older adults is a result of their having fewer cognitive resources. That is, according to the DIT, older adults maintain well-being via two processes, the first being affect optimisation, an automatic tendency to engage in processes that maintain well-being; the second being affective complexity, the ability to restructure positive and negative affect into more complex representations. Labouvie-Vief et al. (2007) propose that as older adults' cognitive resources decrease, so too does their ability to utilise affective complexity, however they are able to maintain emotional well-being by relying on affective optimisation. That is, older adults can compensate for diminished cognitive resources by relying on more automatic optimisation strategies that involve minimising negative and increasing positive affect. From this perspective, then, rather than resulting from explicit and controlled regulatory processes, older adult positivity effects are the consequence of a process that occurs rapidly and automatically following stimulus presentation.

Studies that have examined evidence for whether the SST or DIT can best explain older adult's processing of positive and negative facial expression have mostly used the dot probe technique that involves the lateralised presentation of two expressive faces and the detection of a probe that appears at the location of one of them (Gronchi et al., 2018; Orgeta, 2011; Panebianco et al., 2022). The evidence is mixed, with some results supporting the DIT by showing an early bias to attend to happy faces, i.e. within 100 ms (Gronchi et al., 2018), but others showing that the avoidance of negative faces is slow, about 500 ms (Orgeta, 2011). What is clear from these studies, however, is that older adults can orient to positive expression very quickly. Studies have also examined whether the positivity effect requires attention. For example, Allard and Isaacowitz (2008) presented a series of positive, neutral, and negatively-valenced pictures in full and divided attention conditions and measured fixation times. The results showed that older adults had higher fixation percentages toward positive relative to negative images (a positivity effect) even in the divided attention condition; a result consistent with the idea that at least some aspects of the positivity effect are automatic rather than controlled.

So, how might the current masked repetition results be explained within the DIT framework? The DIT proposes that older adults are more likely to use simplifying processing heuristics that promote positivity. The dot probe results above (Gronchi et al., 2018) indicate that older adults can orient to a happy face even when it is only presented for 100 ms. Plausibly when there is only a single face (as in the current priming paradigm) older adults could rapidly and automatically orient within the face to a region that signals a happy expression, i.e. the oral region (Calder et al., 2000; Smith et al., 2005;

Wegrzyn et al., 2017). This proposal is consistent with the general tendency for older adults to look more at the lower part of a face (Birmingham et al., 2018; Circelli et al., 2013). Once the oral region is attended, an initial processing heuristic could be that if the mouth gesture is consistent with a smile then this is evidence of a positive expression (happy), with this initial hypothesis facilitating subsequent processing. We suggest that for older adults, the repetition priming effect consists of this early prime processing being transferred to the processing of a happy target. The reason why the angry prime expression did not produce priming is because this processing heuristic involves attending to the lower face. That is, this would affect the initial pickup of information relevant to recognising anger, since important information about this expression comes from the upper half of the face (Calder et al., 2000; Smith et al., 2005; Wegrzyn et al., 2017). Ultimately, this orientation to less diagnostic face region would be overcome when sufficient information from the target is processed and information consistent with an angry expression would dominate, but it would mean that target processing would not receive a head start from the prime (hence no priming).

The idea that older adults initially do not pick up anger expression information may appear to be at odds with the results of Bailey and Henry (2009) who examined whether older and younger adults implicitly mimicked an angry expression by measuring corrugator muscle activity. They showed that when viewing an angry compared to control faces (happy and neutral) both older and younger adults showed increased corrugator muscle activity that did not significantly differ. The Bailey and Henry (2009) study examined two time periods after an angry face was displayed, early (200–500 ms) and late (500–800 ms) that are much longer than the intervals considered in the current study. However, it is interesting to note that the data for the early period indicated the younger adults' EMG increase to an angry face was over twice the size of the older adults' response (which was only slightly more than the control). This pattern is consistent with the idea that when a face is presented older adult's attend more to the mouth region and reorient to other face regions only later on.

Category priming for older adults

For older adults, category priming was found for the longer priming-target SOAs in Experiment 2, only for the Happy targets; and there was a tendency for a negative priming effect from the disgust primes. Once again, the DIT inspired idea that older adults use automatic simple processing heuristics to promote positivity seems relevant. That is, on prime presentation older adults attend to the mouth region, and an initial hypothesis about the expression is developed based on whether mouth gesture could be consistent with a smile. Thus, when surprise is presented with the mouth gesture having some similarity to a smile, i.e. an open mouth, prime processing (priming) will accrue to the analysis of the Happy target compared to the neutral face baseline. This priming effect should be weaker than when an actual smiling face has been presented (i.e. the happy prime) and may take more time to time to develop (since only the mouth gesture for surprise is like that of happy). What about when the disgust prime is presented before a negative (Angry) target? Once again, the mouth gesture of disgust has an aspect of a smile (visible teeth), and this may initially bias the analysis towards the positive, happy expression which would delay the decision to be made on the negative target.

Repetition but no category priming for younger adults

The repetition priming results for younger adults are consistent with the proposal that priming is based on the prime accessing a stored representation and that priming accrues when target processing uses this pre-activated information. That is, we suggest that younger adults map the results of feature and expression analysis of the prime to a stored representation (the emotion category happy or angry), that provides semantic information about the valence of the expression. Priming occurs when the target response uses this activated information in the valence decision. We propose this two-step process, in which priming was mediated via a specific emotion representation, because there was no significant valence category priming, i.e. no evidence that the target valence response was directly primed by an implicit response generated by the prime. Indeed, it is likely that implicit valence responses were never generated since participants never responded to the surprise or angry tokens. Finally, as mentioned in the discussion of Experiment 2, with longer prime durations positive priming may have been greater than that of negative priming because happy has no competitors and this would lead to a greater activation of its stored representation over time (in a competitive activation/inhibition model).

In conclusion, we found older adults showed masked repetition priming for happy but not angry target expressions whereas younger adults showed priming for both. This finding suggests that older adults have problems in processing angry expressions at a relatively early stage of emotion recognition process. We proposed an explanation for older adult's lack of priming for Angry targets based on the idea that older adults engage a face-region based feature processing strategy that affects way that older adults initially process angry expressions. If older adults are using a simple feature strategy, then this could be tested in future experiments that uses prime faces that consist only of selected face features (e.g. a face with only a smile, etc). Another possibility would be to examine older adults priming for angry faces in conjunction with eye tracking. Such a combination of methods would help overcome a criticism of studies of older adults gaze fixations of emotional faces, that they do not indicate how the information picked up by different scanning patterns is used in emotion categorisation (Smith et al., 2018; Yitzhak et al., 2021). Ideally, future studies should also conduct a between age-group comparison; of course, to adequately examine age differences in emotion priming would require a much larger sample than that currently used (see Brysbaert, 2019).

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The second and last authors acknowledge support from Australian Research Council grant number: DP200102188.

References

Allard, E. S., & Isaacowitz, D. M. (2008). Are preferences in emotional processing affected by distraction? Examining the age-related positivity effect in visual fixation within a dual-task paradigm. *Aging, Neuropsychology, and Cognition*, *15*(6), 725–743. https://doi.org/10.1080/13825580802348562

Bailey, P. E., & Henry, J. D. (2009). Subconscious facial expression mimicry is preserved in older adulthood. *Psychology and Aging*, *24*(4), 995–1000. https://doi.org/10.1037/a0015789

Bates, D., Kliegl, R., Vasishth, S., & Baayen, H. (2015). Parsimonious mixed models. https://arxiv.org/abs/1506.04967.

Becker, D. V., & Rheem, H. (2020). Searching for a face in the crowd: Pitfalls and unexplored possibilities. *Attention, Perception, & Psychophysics*, *82*(2), 626–636. https://doi.org/10.3758/s13414-020-01975-7

Becker, D. V., & Srinivasan, N. (2014). The vividness of the happy face. *Current Directions in Psychological Science*, *23*(3), 189–194. https://doi.org/10.1177/0963721414533702

Birmingham, E., Svärd, J., Kanan, C., & Fischer, H. (2018). Exploring emotional expression recognition in aging adults using the moving window technique. *PLoS One*, *13*(12), e0208767. https://doi.org/10.1371/journal.pone.0205341

Borson, S., Scanlan, J., Brush, M., Vitaliano, P., & Dokmak, A. (2000). The mini-Cog: A cognitive 'vital signs' measure for dementia screening in multi-lingual elderly. *International Journal of Geriatric Psychiatry*, *15*(11), 1021–1027. https://doi.org/10.1002/1099-1166(200011)15:11<1021::AID-GPS234>3.0.CO;2-6

Brysbaert, M. (2019). How many participants Do We have to include in properly powered experiments? A tutorial of power analysis with reference tables. *Journal of Cognition*, *2*(1), 1–38. https://doi.org/10.5334/joc.72

Calder, A. J., Young, A. W., Keane, J., & Dean, M. (2000). Configural information in facial expression perception. *Journal of Experimental Psychology: Human Perception and Performance*, *26*(2), 527–551. https://doi.org/10.1037//0096-1523.26.2.527

Calvo, M. G., Fernández-Martín, A., & Nummenmaa, L. (2012). Perceptual, categorical, and affective processing of ambiguous smiling facial expressions. *Cognition*, *125*(3), 373–393. https://doi.org/10.1016/j.cognition.2012.07.021

Calvo, M. G., & Nummenmaa, L. (2008). Detection of emotional faces: Salient physical features guide effective visual search. *Journal of Experimental Psychology: General*, *137*(3), 471–494. https://doi.org/10.1037/a0012771

Carstensen, L. L. (2006). The influence of a sense of time on human development. *Science*, *312*(5782), 1913–1915. https://doi.org/10.1126/science.1127488

Circelli, K. S., Clark, U. S., & Cronin-Golomb, A. (2013). Visual scanning patterns and executive function in relation to facial emotion recognition in aging. *Aging, Neuropsychology, and Cognition*, *20*(2), 148–173. https://doi.org/10.1080/13825585.2012.675427

Coelho, C. M., Cloete, S., & Wallis, G. (2010). The face-in-the-crowd effect: When angry faces are just cross (es). *Journal of Vision*, *10*(1), 7–7. https://doi.org/10.1167/10.1.7

Dixon, W. J., & Yuen, K. K. (1974). Trimming and winsorization: A review. *Statistische Hefte*, *15*(2-3), 157–170. https://doi.org/10.1007/BF02922904

Forster, K. I. (1999). The microgenesis of priming effects in lexical access. *Brain and Language*, *68*(1-2), 5–15. https://doi.org/10.1006/brln.1999.2078

Forster, K. I., & Davis, C. (1984). Repetition priming and frequency attenuation in lexical access. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *10*(4), 680–698. https://doi.org/10.1037/0278-7393.10.4.680

Forster, K. I., & Forster, J. C. (2003). DMDX: A windows display program with millisecond accuracy. *Behavior Research Methods, Instruments, and Computers*, *35*(1), 116–124. https://doi.org/10.3758/BF03195503

Gomez, P., Perea, M., & Ratcliff, R. (2013). A diffusion model account of masked versus unmasked priming: Are they qualitatively different? *Journal of Experimental Psychology: Human Perception and Performance*, *39*(6), 1731–1740. https://doi.org/10.1037/a0032333

Gonçalves, A. R., Fernandes, C., Pasion, R., Ferreira-Santos, F., Barbosa, F., & Marques-Teixeira, J. (2018). Effects of age on the identification of emotions in facial expressions: A meta-analysis. *PeerJ*, *6*, e5278. https://doi.org/10.7717/peerj.5278

Gronchi, G., Righi, S., Pierguidi, L., Giovannelli, F., Murasecco, I., & Viggiano, M. P. (2018). Automatic and controlled attentional orienting in the elderly: A dual-process view of the positivity effect. *Acta Psychologica*, *185*, 229–234. https://doi.org/10.1016/j.actpsy.2018.02.008

Hahn, S., Carlson, C., Singer, S., & Gronlund, S. D. (2006). Aging and visual search: Automatic and controlled attentional bias to threat faces. *Acta Psychologica*, *123*(3), 312–336. https://doi.org/10.1016/j.actpsy.2006.01.008

Hansen, C. H., & Hansen, R. D. (1988). Finding the face in the crowd: An anger superiority effect. *Journal of Personality and Social Psychology*, *54*(6), 917–924. https://doi.org/10.1037/0022-3514.54.6.917

Harry, B., Davis, C., & Kim, J. (2012). Subliminal access to abstract face representations does not rely on attention. *Consciousness and Cognition*, *21*(1), 573–583. https://doi.org/10.1016/j.concog.2011.11.007

Johansson, M., Mecklinger, A., & Treese, A. C. (2004). Recognition memory for emotional and neutral faces: An event-related potential study. *Journal of Cognitive Neuroscience*, *16*(10), 1840–1853. https://doi.org/10.1162/0898929042947883

Kauschke, C., Bahn, D., Vesker, M., & Schwarzer, G. (2019). The role of emotional valence for the processing of facial and verbal stimuli—Positivity or negativity bias? *Frontiers in Psychology*, *10*, 1654. https://doi.org/10.3389/fpsyg.2019.01654

Kiesel, A., Kunde, W., Pohl, C., & Hoffmann, J. (2006). Priming from novel masked stimuli depends on target set size. *Advances in Cognitive Psychology*, *2*(1), 37–45. https://doi.org/10.2478/v10053-008-0043-y

Kim, J., & Davis, C. (2003). Task effects in masked cross-script translation and phonological priming. *Journal of Memory and Language*, *49*(4), 484–499. https://doi.org/10.1016/S0749-596X(03)00093-7

Kunde, W., Kiesel, A., & Hoffmann, J. (2003). Conscious control over the content of unconscious cognition. *Cognition*, *88*(2), 223–242. https://doi.org/10.1016/s0010-0277(03)00023-4.

Labouvie-Vief, G. (2003). Dynamic integration affect, cognition, and the self in adult-hood. *Current Directions in Psychological Science*, *12*(6), 201–206. https://doi.org/10.1046/j.0963-7214.2003.01262.x

Labouvie-Vief, G., Diehl, M., Jain, E., & Zhang, F. (2007). Six-year change in affect optimization and affect complexity across the adult life span: A further examination. *Psychology and Aging*, *22*(4), 738–751. https://doi.org/10.1037/0882-7974.22.4.738

Langner, O., Dotsch, R., Bijlstra, G., Wigboldus, D. H. J., Hawk, S. T., & van Knippenberg, A. (2010). Presentation and validation of the Radboud faces database. *Cognition and Emotion*, *24*(8), 1377–1388. https://doi.org/10.1080/02699930903485076

Lenth, R. V., Buerkner, P., Herve, M., Love, J., Riebl, H., & Singmann, H. (2019). Estimated marginal means, aka least-squares means. R package version 1.5.1. https://cran.r-project.org/package = emmeans.

Lindell, A. K., & Savill, N. J. (2010). Time to turn the other cheek? The influence of left and right poses on perceptions of academic specialisation. *Laterality*, *15*(6), 639–650. https://doi.org/10.1080/13576500903201784

Lüdecke, D., Patil, I., Ben-Shachar, M. S., Wiernik, B. M., & Makowski, D. (2022). easystats: Framework for Easy Statistical Modeling, Visualization, and Reporting. CRAN. Available from https://easystats.github.io/easystats/.

Mather, M., & Knight, M. R. (2006). Angry faces get noticed quickly: Threat detection is not impaired among older adults. *The Journals of Gerontology: Series B*, *61*(1), 54–P57. https://doi.org/10.1093/geronb/61.1.P54

Matuschek, H., Kliegl, R., Vasishth, S., Baayen, H., & Bates, D. (2017). Balancing type I error and power in linear mixed models. *Journal of Memory and Language*, *94*, 305–315. https://doi.org/10.1016/j.jml.2017.01.001

Öhman, A., Lundqvist, D., & Esteves, F. (2001). The face in the crowd revisited: A threat advantage with schematic stimuli. *Journal of Personality & Social Psychology*, *80*(3), 381–396. https://doi.org/10.1037/0022-3514.80.3.381

Orgeta, V. (2011). Avoiding threat in late adulthood: Testing two life span theories of emotion. *Experimental Aging Research*, *37*(4), 449–472. https://doi.org/10.1080/0361073X.2011.590759

Panebianco, M., Caprì, T., Panebianco, M., & Fabio, R. A. (2022). The role of automatic and controlled processes in the positivity effect for older adults. *Aging Clinical and Experimental Research*, *34*(4), 905–911. https://doi.org/10.1007/s40520-021-02007-6

Purcell, D. G., & Stewart, A. L. (2010). Still another confounded face in the crowd. *Attention, Perception, & Psychophysics*, *72*(8), 2115–2127. https://doi.org/10.3758/BF03196688

Reed, A. E., & Carstensen, L. L. (2012). The theory behind the age-related positivity effect. *Frontiers in Psychology*, *3*, 339. https://doi.org/10.3389/fpsyg.2012.00339

Rohr, M., Degner, J., & Wentura, D. (2012). Masked emotional priming beyond global valence activations. *Cognition & Emotion*, *26*(2), 224–244. https://doi.org/10.1080/02699931.2011.576852

Rohr, M., & Wentura, D. (2021). Degree and complexity of non-conscious emotional information processing–a review of masked priming studies. *Frontiers in Human Neuroscience*, *15*, 329. https://doi.org/10.3389/fnhum.2021.689369

Rosen, H. J., Wilson, M. R., Schauer, G. F., Allison, S., Gorno-Tempini, M.-L., Pace-Savitsky, C., … Miller, B. L. (2006). Neuroanatomical correlates of impaired recognition of emotion in dementia. *Neuropsychologia*, *44*(3), 365–373. https://doi.org/10.1016/j.neuropsychologia.2005.06.012

Ruffman, T., Ng, M., & Jenkin, T. (2009). Older adults respond quickly to angry faces despite labeling difficulty. *The Journals of Gerontology: Series B*, *64B*(2), 171–179. https://doi.org/10.1093/geronb/gbn035

Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology*, *39*(6), 1161–1178. https://doi.org/10.1037/h0077714

Savage, R. A., Becker, S. I., & Lipp, O. V. (2016). Visual search for emotional expressions: Effect of stimulus set on anger and happiness superiority. *Cognition and Emotion*, *30*(4), 713–730. https://doi.org/10.1080/02699931.2015.1027663

Savage, R. A., Lipp, O. V., Craig, B. M., Becker, S. I., & Horstmann, G. (2013). In search of the emotional face: Anger versus happiness superiority in visual search. *Emotion*, *13*(4), 758–768. https://doi.org/10.1037/a0031970

Schmidt, F., Haberkamp, A., & Schmidt, T. (2011). Dos and don'ts in response priming research. *Advances in Cognitive Psychology*, *7*(-1), 120–131. https://doi.org/10.2478/v10053-008-0092-2

Singmann, H., Bolker, B., Westfall, J., Aust, F., Ben-Shachar, M. S., Højsgaard, S., … Christensen, R. H. B. (2016). *afex: Analysis of factorial experiments. R package version 0.16-1*. https://cran.r-project.org/package = afex.

Smith, M. L., Cottrell, G. W., Gosselin, F., & Schyns, P. G. (2005). Transmitting and decoding facial expressions. *Psychological Science*, *16*(3), 184–189. https://doi.org/10.1111/j.0956-7976.2005.00801.x

Smith, M. L., Grühn, D., Bevitt, A., Ellis, M., Ciripan, O., Scrimgeour, S., … Ewing, L. (2018). Transmitting and decoding facial expressions of emotion during healthy aging: More similarities than differences. *Journal of Vision*, *18*(9), 10–10. https://doi.org/10.1167/18.9.10

Wegrzyn, M., Vogt, M., Kireclioglu, B., Schneider, J., & Kissler, J. (2017). Mapping the emotional face. How individual face parts contribute to successful emotion recognition. *PloS One*, *12*(5), e0177239. https://doi.org/10.1371/journal.pone.0177239

Willenbockel, V., Sadr, J., Fiset, D., Horne, G. O., Gosselin, F., & Tanaka, J. W. (2010). Controlling low-level image properties: The SHINE toolbox. *Behavior Research Methods*, *42*(3), 671–684. https://doi.org/10.3758/BRM.42.3.671

Yitzhak, N., Pertzov, Y., & Aviezer, H. (2021). The elusive link between eye-movement patterns and facial expression recognition. *Social and Personality Psychology Compass*, *15*(7), e12621, 1–15. https://doi.org/10.1111/spc3.12621