Simulation-based learning influences real-life attitudes

Philipp C. Paulus^{1, a, b, }, Aroma Dabas^{a, c}, Annalena Felber^a, and Roland G. Benoit^a

^aMax Planck Research Group: Adaptive Memory, Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany

^bInternational Max Planck Research School NeuroCom, Leipzig, Germany

^cBerlin School of Mind and Brain, Humboldt-Universität zu Berlin, Berlin, Germany

Humans can vividly simulate hypothetical experiences. This ability draws on our memories (e.g., of familiar people and locations) to construct imaginings that resemble real-life events (e.g., of meeting a person at a location). Here, we examine the hypothesis that we also learn from such simulated episodes much like from actual experiences. Specifically, we show that the mere simulation of meeting a familiar person (unconditioned stimulus; US) at a known location (conditioned stimulus; CS) changes how people value the location. We provide key evidence that this simulation-based learning strengthens pre-existing CS-US associations and that it leads to a transfer of valence from the US to the CS. The data thus highlight a mechanism by which we learn from simulated experiences.

episodic simulation; attitude change; transfer of valence; long-term memory; evaluative conditioning

paulus@cbs.mpg.de | philipp.paulus@psychologie.uni-freiburg.de

Introduction

Humans possess the remarkable ability to vividly imagine hypothetical episodes that could have happened in the past or may take place in the future (de Brigard & Parikh, 2019; Schacter, Addis, & Buckner, 2007; Suddendorf & Corballis, 2007). Such episodic simulation shares many similarities with episodic memory (Schacter, Benoit, & Szpunar, 2017). For example, it is largely supported by the same neural network (Benoit & Schacter, 2015) and exhibits similar phenomenological qualities (D'Argembeau & Van der Linden, 2004). These commonalities suggest that episodic simulations are based on the recollection of memories (e.g., of known people and locations) that get flexibly recombined into fictitious episodes (e.g., of meeting a person at a location) (Benoit, Szpunar, & Schacter, 2014; Schacter et al., 2007).

Given this strong relationship between simulating and remembering, can we also *learn* from imagined events much as we learn from actual past experiences? Evidence from motor learning supports this idea: Imagining to execute a specific action can boost performance akin to actually carrying out that action (Driskell, Copper, & Moran, 1994). Moreover, fear conditioning can arise not only from the actual experience of an unconditioned stimulus (US) but also from just

imagining an aversive event (e.g., stepping onto a thumbtack) (Mueller, Sperl, & Panitz, 2019).

Simulated experiences also seem to shape our attitudes in a similar fashion as real experiences. We have recently described that merely imagining a meeting with a known person (serving as US) at an initially neutral location (serving as conditioned stimulus; CS) changes how much we like the location (Benoit, Paulus, & Schacter, 2019). These simulations induced a positive shift in attitude that was more pronounced following imaginary meetings with liked than with disliked people. This effect resembles the phenomenon of evaluative conditioning, where the actual co-occurrence of a positive or negative US leads to a transfer of its respective valence to a paired CS (Hofmann, De Houwer, Perugini, Baeyens, & Crombez, 2010; Walther, Halbweisen, & Blask, 2018; see also Wimmer & Shohamy, 2012).

Here, we seek to further establish the mechanism that supports simulation-based learning and to gauge its similarity with experience-based learning. First, evaluative conditioning has been argued to involve an associative integration of the US and CS (Forester, Halbeisen, Walther, & Kamp, 2020; Madan & Kensinger, 2021; Palombo, Elizur, Tuen, Te, & Madan, 2021; Stahl & Aust, 2018). If simulation-based learning is based on a similar integrative mechanism, we expect simulations to strengthen the associations between the paired US (here: the imagined person) and CS (here: the imagined location) (see also Benoit et al., 2019). By this, simulations would reshape the very semantic space that they operate on.

Second, we further scrutinize whether simulation-based changes in attitude indeed reflect a transfer of valence from the US to the CS. Compared to a neutral baseline condition, simulations featuring liked people should cause an upward shift and simulations with disliked people a downward shift in the liking of the locations. Third, we hypothesized that the integrative simulations induce an affective experience consistent with the nature of the US (Benoit et al., 2019). That is, we predict greater skin conductance levels for simulations featuring liked and disliked compared to neutral people, and expect that the experienced pleasantness is contingent on the valence of the US. Finally, we examine how simulations cause this transfer of affective valence from the person to the location. Specifically, we hypothesize that the affective quality of the simulated episode (i.e., the perceived pleasantness) mediates this effect.

¹Present address: Department of Psychology, Neuropsychology, University of Freiburg, Engelbergerstr. 41, D-79106 Freiburg, Germany. philipp.paulus@psychologie.uni-freiburg.de

Materials and methods

Participants. We recruited 48 healthy adults from the database of the Max Planck Institute for Human Cognitive and Brain Sciences, all of which had normal or corrected-to-normal vision, provided written informed consent, and received monetary compensation for participating. The experimental protocol was approved by the Ethics Committee at the Medical Faculty, Leipzig University, Germany (reference number 054/19-ek). Two participants had to be excluded due to missing data and three for an insufficient number of provided disliked, neutral, or liked people (see below). We thus included data from 43 participants (22 females, 21 males; *mean* age = 24.2 years, *SD* = 3.1, *range*: 19 to 35). The included sample yields approximately 80% power to detect an effect half the size as in Benoit et al. (2019). Due to recording errors, five further participants were excluded from analyses of the psychophysiological data (leaving 38 participants; 20 females, 18 males, *mean* age = 24.4 years, *SD* = 3.2, *range*: 19 to 35).

Task and procedures. The procedure, adapted from Benoit et al. (2019), consisted of a preparation and a simulation session (Fig. 1). During the preparation session (*mean* duration = 4.5 h, *SD* = 1.2, *range*: 2.8 to 7.2), participants provided 150 familiar locations with the help of online maps and 150 personally known people using their contact lists as aid. Specifically, they were instructed to name the 100 people they liked most, 30 they felt neutral towards, and 20 they disliked. This was done to ensure sufficient variance in liking to form all valence conditions and in familiarity to better match the conditions on that variable. Participants rated all people and locations (i) according to their familiarity (1: not at all, 5: intermediate, 9: very much) and (ii) according to their liking (1: not at all, 5: neutral, 9: very much) as an index of valence.

We selected 30 neutral locations (*mean* = 5.06, *SD* = 0.28) as well as ten disliked (*mean* = 1.96, *SD* = 0.55), ten neutral (*mean* = 5.13, *SD* = 0.21), and ten liked people (*mean* = 7.8, *SD* = 0.47) (see Supplement 1 for details of the selection procedure). We then randomly assigned each neutral location (i.e., the CS) to a unique person that was either liked, neutral, or disliked (i.e., the US).

We quantified the pre-experimental associations among the selected people and locations using the multiple-arrangements task (Kriegeskorte & Mur, 2012): Participants arranged the 60 names on a circular arena so that strongly related exemplars were placed closely together and unrelated exemplars at opposing sides of the arena (Fig. 1C). On the first trial, participants arranged all people and locations. On subsequent trials, we adaptively zoomed into different subsets to gain more fine-grained information. As a measure of associatedness, we computed the difference score between the proximity of a given person to its paired location (*within pair*) and the average proximity of that person to all other locations (*outside pair*) (Nili, Walther, Alink, & Kriegeskorte,

2020; Paulus, Charest, & Benoit, 2020).

Participants returned for the simulation session (*mean* delay = 1.1 day, *SD* = 0.4, *range*: 1 to 2). Each trial commenced with a 0.5 s fixation period, followed by the simulation period during which a person-location pairing was presented for 7.5 s. During this time, participants vividly simulated interacting with the person in a manner that would be specific for the location (e.g., at a restaurant, discussing appetizers). Participants rated the vividness of their simulation (1: not at all, 5: very much) within 3 s. The remainder of this time, if any, was added to the inter trial interval that lasted for 3 s plus a jitter (0-8 s in 2 s intervals). After participants had been trained on the task, we randomly presented all pairs once in each of three runs. For the second and third encounter of the pairs, participants were instructed to simulate the same episode as in the original encounter. They were asked to use the additional time to make their simulations more vivid or to imagine how the episode would continue to unfold (Fig. 1D).

Afterwards, participants rated their liking of each person and location as well as the plausibility (1: very implausible, 5: somewhat, 9: very plausible) and pleasantness of the imagined meetings (1: very unpleasant, 5: neutral, 9: very pleasant). They then again indicated the person-location associations using the multiple-arrangements task. After finishing this task, participants completed the Big Five Inventory (Rammstedt & John, 2005) as well as questionnaires on mind wandering and their ability to imagine visual scenes (not reported). A subsample was also invited to pilot a task similar to an implicit association test currently in development (not reported).

Psychophysiological recordings and analysis. Skin conductance responses (SCRs) were recorded using Ag/AgCl electrodes attached to the thenar and hypothenar of the non-dominant hand. Signals were recorded at 1,000 Hz using a Biopac (BIOPAC Systems Inc., Santa Barbara, CA) MP 150 data acquisition system running AcqKnowledge (4.3). For exploratory purposes, we also monitored heartbeats (not reported).

We quantified SCRs during the simulation trials following the recommendations of the Society for Psychophysiological Research (Boucsein et al., 2012) implemented in the Psycho-Physiological Modelling toolbox (4.0.2, <http://bachlab.org/pspm>) in Matlab 2017b (9.3, Mathworks, Natick, MA).

Statistical analysis. Statistical analyses were done in R (3.6.2, www.r-project.org) using repeated measures ANOVAs including the factors *Valence* of the US (*disliked*, *neutral*, *liked*) and, where appropriate, *Time* (*pre*-, *post*-simulation). We accounted for violations of sphericity using the Greenhouse-Geisser method and, in planned follow-up tests, for multiple comparisons using Holm's method. Whenever a Shapiro-Wilk test indicated a deviation from normality,

A. Listing known people and locations

People	Locations
001. Clara Paulus	001. Falland bakery
002. Justus Paulus	002. MPI elevator
...	...
150. Ann-Kristin Meyer	150. Konsum Kochstr.

B. Pre-simulation rating: liking and familiarity

Ann-Kristin Meyer

Liked?

1 5 9
not at all neutral very much

Familiar?

1 5 9
not at all very much

C. Measuring associations

D. Simulating episodes

E. Post-simulation rating: liking

MPI elevator

Liked?

1 5 9
not at all very much

Ann-Kristin Meyer

Liked?

1 5 9
not at all very much

F. Post-simulation rating: pleasantness and plausibility

Ann-Kristin Meyer MPI elevator

Pleasant?

1 5 9
not at all neutral very much

Plausible?

1 5 9
not at all very much

Fig. 1. Overview of the experimental procedure. **A.** Participants provided lists of 150 known people and locations. **B.** Participants rated how much they liked and how well they knew the people and locations. We used these ratings to select 10 disliked, 10 neutral, 10 liked people, and 30 neutral locations. Each selected person was then randomly paired with one of the locations. **C.** Both before and after the main part of the experiments, participants arranged the selected people and locations according to their associations. Participants placed two exemplars closely together if they associated them strongly and far apart if they did not. **D.** Participants repeatedly simulated imaginary encounters with the known people at their paired location. After the simulation, participants rated the vividness of the simulated episode. **E.** After the simulation task, participants rated again how much they liked the selected people and locations. **F.** Participants also indicated how pleasant the simulated episode had been and how plausible it would be to actually meet the person at the paired location.

we used Wilcoxon rather than Student's *t*-tests. We tested our directed hypotheses with one-tailed tests.

Results

Simulations strengthen associations between paired people and locations. We first tested whether episodic simulations strengthened the associations between people and their paired locations by comparing their associatedness on the pre- and post-test.

The rANOVA revealed a significant effect of *Time* only ($F(1,42) = 10.59, p = .002, \eta_G^2 = 0.06$; *Valence*: $F(1.96,82.3) = 0.61, p = .542, \eta_G^2 = 0.004$; *Time* $\times$ *Valence*: $F(1.96,82.28) = 1.37, p = .259, \eta_G^2 = 0.004$). Thus, episodic simulations strengthened the associations between the people and their paired locations (Fig. 2A). Somewhat contrary to a related finding (Szpunar, Addis, & Schacter, 2012) this was the case regardless of valence. We next examine whether the integration of memory representations was accompanied by the

predicted transfer of valence.

Episodic simulations change the liking of the simulated locations. We predicted a transfer of positive valence from the liked, and a transfer of negative valence from the disliked people. To test this prediction, we assessed how the liking of the paired locations changed from the pre- to the post-rating. We observed a significant effect of *Time* ($F(1,42) = 99.98, p < .001, \eta_G^2 = 0.32$), no effect of *Valence* ($F(1.88, 78.90) = 1.95, p = .152, \eta_G^2 = 0.01$), but, crucially, the significant interaction ($F(1.91, 80.25) = 12.39, p < .001, \eta_G^2 = 0.04$; Fig. 2B left).

The *Time* effect reflected a positive shift in liking for all locations. This shift may be due to generic effects such as mere exposure (Benoit et al., 2019; Zajonc, 2001) or increased availability (Tversky & Kahneman, 1974). To control for this generic upward shift, we used the locations from the neutral condition as a baseline. We thus could unmask possible valence-specific effects. Specifically, if the interaction truly

A. Simulations strengthen associations B. Simulations induce a transfer of valence from the US to the CS

Fig. 2. Simulation-based learning of real life attitudes. **A.** Episodic simulations strengthen already existing associations between paired people and locations, irrespective of the person's valence. **B. Left:** Episodic simulations induce a transfer of valence from the person (US) to their paired location (CS). **Right:** Simulated episodes with disliked people yielded a significant transfer of negative valence and episodes with liked people a significant transfer of positive valence as compared to the neutral baseline condition. Dots and whiskers in A, B left: mean $\pm$ SEM. Dots in B right: condition mean individual participants, Box-plots: center line, median; box-limits, first and third quartile; whiskers, 1.5x interquartile range. *** - $p < .001$, ** - $p < .01$, * - $p < .05$.

reflects a transfer of valence, we expected *opposite* shifts in liking for locations imagined with liked versus disliked people compared to those imagined with neutral people.

Indeed, relative to the neutral baseline condition, simulations with liked people yielded the significant relative upward shift ($t(42) = 2.39$, $p = .011$, $d = 0.36$), whereas simulations with disliked people yielded the significant relative downward shift ($t(42) = 2.88$, $p = .003$, $d = 0.44$; Fig. 2B right). The analyses thus provide evidence for opposite effects of imagining positive versus negative US. We obtained the same effect when statistically controlling for the familiarity of the people (see Supplement 2 and Fig. S1).

Stronger affective responses in simulations featuring liked and disliked people. We next tested whether simulations induce an affective experience that is contingent on the valence of the US. We therefore examined two facets of participants' affective responses: (i) Their arousal as indexed by skin conductance and (ii) the valence of their experience as indexed by the pleasantness ratings.

The analysis of the SCRs revealed a significant effect of *Valence* ($F(1.66, 61.5) = 5.59$, $p = .009$, $\eta_G^2 = 0.02$). Simulations featuring liked ($W = 176$, $p = .002$, $r = 0.46$; Shapiro-Wilk: $W = 0.69$, $p < .001$) and disliked people elicited stronger SCRs ($W = 604$, $p < .001$, $r = 0.55$; Shapiro-Wilk: $W = 0.81$, $p < .001$) than simulations featuring neutral people (with no difference for disliked versus liked people; $W = 365$, $p = .943$, *two-tailed*, $r = 0.01$; Shapiro-Wilk: $W = 0.91$, $p = .005$). The SCR data thus corroborate a stronger arousal during simulations including liked and disliked people (Fig. 3A).

The analysis of the episodes' pleasantness yielded a significant effect of *Valence* of the person ($F(1.51, 63.56) = 292.21$, $p < .001$, $\eta_G^2 = 0.82$). As expected, planned comparisons with the neutral condition revealed significantly lower pleasant-

ness for simulations featuring disliked ($t(42) = 16.06$, $p < .001$, $d = 2.45$) and greater pleasantness for simulations featuring liked people ($t(42) = 11.23$, $p < .001$, $d = 1.71$) (Fig. 3B).

The transfer of valence is mediated by the experienced pleasantness. We had hypothesized that the experienced pleasantness would account for the transfer of valence from the US to the CS. Indeed, a multi-level mediation analysis revealed a mediation of the transfer of valence from the person to its paired location by the pleasantness of the simulated episode. The indirect effect was 0.108 ($p < .001$) and the average direct effect was -0.043 ($p = .048$) (Fig. 3C). Thus, episodic simulations induce an affective experience aligned with the valence of the US. This experience, in turn, accounts for the ensuing changes in valence of the CS.

Exploratory: Neuroticism and simulation-based learning. Neuroticism is one risk factor for the development of mood and anxiety disorders (Bulley, Henry, & Suddendorf, 2017; Lahey, 2009; Miloyan, Pachana, & Suddendorf, 2014). One key hallmark of these disorders is an extensive engagement in future directed cognitions (Miloyan et al., 2014). Given that individuals scoring high in neuroticism exhibit reduced spontaneous positive future thought (especially those with depression; Gamble, Moreau, Tippet, & Addis, 2019; MacLeod & Byrne, 1996, we predicted that they would also exhibit weaker learning from simulated positive experiences. We thus explored whether neuroticism is associated with less simulation-based learning in the positive condition. Indeed, individuals higher in neuroticism exhibited a weaker upward shift in liking (i.e., a less positive change from the pre- to the post-test) (Spearman's $\rho = -0.38$, $p = .012$). By contrast, there were no significant relationships between neuroticism and simulation-based learning in the other valence conditions (see Fig. S3 and Table S1, also for exploratory correlations

Fig. 3. The transfer of valence is mediated by the affective experience of the simulated episode. **A.** Evoked skin conductance responses (SCRs) are significantly larger for simulations featuring both disliked and liked people, as compared to the neutral baseline condition. Due to a deviation from normality, tested with a non-parametric test. **B.** Compared to the neutral baseline condition, episodes featuring liked people were experienced as more pleasant and episodes featuring disliked people as less pleasant. **C.** The effect of the liking of the person on the change in liking of the location is mediated by the pleasantness of the simulated episode. *** - $p < .001$, ** - $p < .01$, * - $p < .05$.

with the remaining Big Five traits).

Discussion

Remembering the past and imagining the future share many similarities (Schacter et al., 2007, 2017). Here, we corroborate that we also learn from simulated experiences much as we learn from actual past experiences (Benoit et al., 2019; Driskell et al., 1994; Mueller et al., 2019). Specifically, we build on our previous observation that simulations can change attitudes towards our real-life environment. Changing existing attitudes tends to be more difficult than forming new ones (Jones, Olson, & Fazio, 2010). It is therefore particularly remarkable that simulations affected evaluations of locations that the participants were already personally familiar with. Critically, this study furthers our understanding of the mechanism underlying such simulation-based learning.

We demonstrate that simulations strengthen pre-existing associations between jointly simulated people (US) and locations (CS).² This process may induce experience-dependent plasticity that allows for the transfer of valence from the US to the CS (Barron, Dolan, & Behrens, 2013). Indeed, the episodic integration of the CS and US has been highlighted as a prerequisite for real experiences to induce evaluative conditioning (Palombo et al., 2021; see also Forester et al., 2020; Madan & Kensinger, 2021).

The observed strengthening of the CS-US associations in-

²Consistent with the literature on evaluative conditioning, we refer to the valenced stimuli (i.e., the people) as the US (De Houwer, 2007; Hofmann et al., 2010; Jones et al., 2010). However, from a classical conditioning perspective, they may not strictly be regarded as primary reinforcers. Indeed, from that perspective, our attitude towards the people may already have been shaped by a history of previous reinforcements. The process under investigation could thus also be considered a form of second-order conditioning (Holland & Rescorla, 1975; Rizley & Rescorla, 1972).

icates that mere simulations can fulfil the same prerequisite. Notably, we show that simulations not only establish novel associations (e.g., Martin, Schacter, Corballis, & Addis, 2011). Like real experiences, they can also affect the associative strength of semantic representations, such as of personally familiar people and locations (Renoult, Davidson, Palombo, Moscovitch, & Levine, 2012). Episodic simulations thus seem to modify the overall configuration of the semantic space that they operate on.

How do the integrative simulations mediate the transfer of valence? It has been proposed that evaluative conditioning requires the binding of US and CS features into a common representation (Walther et al., 2018). Our mediation analysis indicates, more specifically, that this transfer hinges on the experienced affect. On the one hand, the experienced affect may directly become integrated into the existing representation of the CS (Madan & Kensinger, 2021). On the other hand, the affective experience may be encoded as an episodic memory. Subsequent deliberations on the CS could then lead to the retrieval of this experience and thus influence its evaluation (Kensinger & Ford, 2020).

However, unlike studies on evaluative conditioning (e.g., Palombo et al., 2021), we did not test whether the episodic integration of US and CS and the ensuing transfer of valence is based on episodic memories of the simulations. We do suggest though that participants likely had formed explicit memories of the person-location pairings. This suggestion is based on the memory performance in prior experiments that had used similar procedures (e.g., Addis, Pan, Vu, Laiser, & Schacter, 2009; Martin et al., 2011), our experimental modifications that would have further strengthened the memories (e.g., smaller number of pairings; more repetitions), and our instructions (i.e., to repeatedly imagine the same episode) that fostered intentional encoding.

Notably, our data moreover demonstrate that simulation-based learning is indeed valence-specific. We were previously unable to quantify unspecific changes arising from general effects such as mere exposure (Zajonc, 2001) or availability (Tversky & Kahneman, 1974). We could thus not determine whether simulations can also cause a downward shift in attitude. By including a neutral condition as a baseline for such generic effects, we have now established that the simulation-based changes are contingent on the valence of the US. In its directionality, the transfer of valence thus resembles the extant literature on experienced-based evaluative conditioning (Hofmann et al., 2010).

The bidirectional transfer of valence has possible clinical implications. Our analysis indicated that people high in neuroticism learn less from positive simulations. They may thus build a model of their environment that is primarily based on negative simulations. This effect may contribute to the development and maintenance of affective disorders (see also Bulley et al., 2017; Renner, Ji, Pictet, Holmes, & Blackwell, 2017). It may accordingly sometimes be more beneficial for one's well-being to stop imaginings of hypothetical events (Benoit, Davies, & Anderson, 2016).

There are several limitations to this work. Notably, the temporal stability of this effect warrants further investigation. The literature on evaluative conditioning indicates that experience-based attitude changes last for extended periods (Jones et al., 2010). The similarities to simulation-based learning suggest that also mere imaginings can have an extended influence.

Moreover, it would be desirable to investigate the question of a dose-response relationship. Does the number of repeated simulations determine the strength of the learning effect as is the case in experience-based learning (Madan & Kensinger, 2021) and is it also governed by similar computational mechanisms? We suggest that our experimental approach provides an avenue for exploring these questions.

To conclude, episodic simulation does not only influence our outlook towards the future (Benoit, Berkens, & Paulus, 2018; Rösch, Stramaccia, & Benoit, 2021). It also constitutes a learning device that influences how we evaluate our everyday environment. Given that people frequently imagine emotional future scenarios (Barsics, Van der Linden, & D'Argembeau, 2016), such simulations may indeed contribute to our view of the world in a similar fashion as our actual experiences.

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COMPETING INTERESTS STATEMENT

The authors declare no competing interests.

AUTHOR CONTRIBUTIONS

Philipp Paulus: Conceptualization, Methodology, Software, Formal analysis, Investigation, Data curation, Writing – Original Draft, Writing – Review & Editing, Visualization. **Aroma Dabas:** Conceptualization, Methodology, Software, Investigation, Writing – Review & Editing. **Annalena Felber:** Investigation, Data curation, Writing – Review & Editing. **Roland Benoit:** Conceptualization, Methodology, Formal analysis, Writing – Original Draft, Writing – Review & Editing, Visualization, Supervision, Funding acquisition.

DATA AND CODE AVAILABILITY

All data, custom code, and the experiment scripts (except for the multiple arrangements task) are publicly available at the Open Science Framework: https://osf.io/9yt7s/?view_only=c532cb3e669749a9ac503b75a601b643

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Supplement 1. Description of the selection algorithm for the people

As in previous studies (Benoit et al., 2019, 2014; Paulus et al., 2020), disliked people tended to also be less familiar than liked ones. In our selection procedure, we thus sought to simultaneously maximize differences in liking while minimizing differences in familiarity (based on the pre-simulation ratings).

In a first step, we split all provided people into disliked (liking-rating of 1-3), neutral (liking-rating of 4-6), and liked (liking-rating of 7-9) people. If there were less than ten people in any of these initial sets, the participant was reimbursed for their time, and not invited to return for the simulation session ($n = 3$).

In a next step, we then identified the person with the lowest liking rating and – if possible – selected people with matching familiarity in the neutral and liked sets. Importantly, we always tried to select those people that were respectively closest to the neutral center (rating of 5) or the positive end of the scale (rating of 9). We repeated this process for all items in the set of disliked people.

If this procedure did not yield complete sets of disliked, neutral, and liked people, we drew 25'000 random samples from the remaining pool of people that would complete the sets. For each of these random samples, we determined the sum of squared familiarity differences between the three conditions in each resulting set. We then selected the sample with the smallest sum of squared familiarity differences between the conditions. This selection was then used in the main part of the experiment.

Supplement 2. Control analysis: Familiarity of the people

Despite our selection process, the people (i.e., the US) still differed in familiarity ($F(1.39, 58.31) = 5.88, p = .011, \eta_G^2 = .01$) (see also Benoit et al., 2019). We sought to statistically control for this possible confound. Specifically, across all valence conditions, we first regressed the familiarity of the people on the change in liking of the locations. This was done separately for each participant. We then subjected the residuals of this regression analysis to another rANOVA. Importantly, this analysis retained the effect of Valence ($F(1.91, 80.16) = 10.44, p < .001, \eta_G^2 = .2$) as well as the relative upward and downward shifts following simulations with liked versus disliked people ($ps < .05$; Fig. S1). The observed effects are thus unlikely to be accounted for by the familiarity of the people.

Supplementary Figure 1.

Fig. S1. A. Episodic simulations induce a transfer of valence from the person (US) to their paired location (CS). **B.** Differences in familiarity between the sets of selected people (US) do not account for differences in the change in liking of the locations (CS).

Supplementary Figure 2.

Fig. S2. A. Participants rated their imaginations significantly less vivid for the negative as compared to the neutral condition ($W = 17, p < .001, r = 0.83$; Wilcoxon test due to a deviation from normality: $W = 0.94, p = .024$) and significantly more vivid for the positive as compared to both the neutral ($t(42) = 4.9, p < 0.001, d = 0.75$) and negative condition ($t(42) = 10.13, p < .001, d = 1.54$). **B.** Participants rated the plausibility of actually meeting a person at its paired location significantly lower for the negative as compared to both the neutral ($t(42) = 4.6, p < .001, d = 0.7$) and positive condition ($t(42) = 4.9, p < .001, d = 0.75$). There was no significant difference in plausibility for the positive as compared to the neutral condition ($t(42) = 0.26, p = .799, d = 0.04$).

Supplementary Figure 3.

Fig. S3. *Positive condition: Following simulations with liked people, individuals higher in neuroticism exhibited a weaker upward shift in liking of the locations. For completeness, we also show the correlations for the negative and neutral conditions, which were both not significant ($ps > .149$). Note that we do not imply that correlations in these conditions are significantly smaller than in the positive condition.*

Supplementary Table 1

Trait	Condition	Spearman's ρ	p	
Neuroticism	Negative	-0.06	.707	
	Neutral	-0.22	.149	
	Positive	-0.38	.012	*
Extraversion	Negative	-0.32	.034	*
	Neutral	-0.06	.687	
	Positive	0.01	.963	
Openness	Negative	0.07	.642	
	Neutral	0.16	.320	
	Positive	-0.06	.708	
Agreeableness	Negative	-0.27	.082	
	Neutral	-0.04	.798	
	Positive	0.00	.987	
Conscientiousness	Negative	0.04	.777	
	Neutral	0.03	.870	
	Positive	0.14	.385	

Note. p -values are uncorrected. * - $p < .05$