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FlashReport

Implicit learning of social predictions

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ABSTRACT

Humans exchange a range of nonverbal social signals in every interaction. It is an open question whether people use these signals, consciously or unconsciously, to guide social behavior. This experiment directly tested whether participants could learn to predict another person's behavior using nonverbal cues in a single interaction, and whether explicit knowledge of the cue–outcome relationship was necessary for successful prediction. Participants played a computerized game of rock–paper–scissors against an avatar they believed was another participant. Sometimes the avatar generated a predictive facial cue before the play. On these trials, participants' win-frequency increased over time, even if they did not acquire explicit knowledge of the predictive cue. The degree to which participants could predict the avatar (wins on cued trials) related to their self-reported liking of the avatar. These findings demonstrate the importance of implicit associative learning mechanisms in guiding social behavior on a moment-to-moment basis during interaction.

Introduction

During social interaction, people exchange large numbers of nonverbal social cues. These range from clearly meaningful emotional expressions (e.g., genuine smiles, Frank, Ekman, & Friesen, 1993) to ambiguous but potentially meaningful behaviors (e.g., eyebrow raises) to meaningless behavioral "noise" (e.g., blinks, small head/body movements). Nonetheless, most people manage to coordinate their own social behavior with that of others and to make sense of others' social cues with relative ease. To accomplish this, it is likely that people choose behaviors based on predictions about their social partners' future actions.

How do people learn to predict others? Research suggests that people use their experiences to develop beliefs about how others will think, feel and act in different situations (e.g., Kliemann, Young, Scholz, & Saxe, 2008; Yoshida, Dolan, & Friston, 2008), which inform subsequent social inferences (Mitchell, 2009; Uleman, Saribay, & Gonzalez, 2008). Consistent with this idea, a long line of research suggests that an interaction history with someone enhances the accuracy of trait judgments of that person (Carney, Colvin, & Hall, 2007; Funder & Colvin, 1988; Funder, Kolar, & Blackman, 1995; Hall & Schmid Mast, 2007) and that people unconsciously associate learned characteristics of one person (competence, fairness) with another, physically similar person (e.g., in hairstyle, facial features, Hill, Lewicki, Czyzewska, & Schuller, 1990; Lewicki, 1986). Facial characteristics are also used to infer trait judgements such as trustworthiness and personality both consciously (Todorov, Mandisodza, Goren, & Hall, 2005) and unconsciously (Sweeny, Grabowecky, Suzuki, & Paller, 2009; Todorov, 2008; van't Wout & Sanfey, 2008).

Although past interactions and stable facial features can inform judgements about what people are like at the trait level, predictions about people's behavior on a moment-to-moment basis during single interactions are likely to rely on more fluid cues (e.g., subtle facial expressions, see Dimberg & Thunberg, 1998; Ekman, 2003). Although this idea has intuitive appeal (Frith & Frith, 2007), it has so far resisted experimental scrutiny because it is difficult to gain precise control over the distribution and predictability of social cues in live interactions.

To overcome this difficulty, we created a quasi-naturalistic interaction in which participants played a computerized game of rock–paper–scissors with what appeared to be a live opponent. Unbeknownst to participants, the opponent was an avatar, constructed of short, pre-recorded films of another person that played continuously during the task. The use of a video-based avatar (rather than a computer-generated one) allowed us complete control over the avatar's behavior, without affecting participants' belief that they played a real opponent. On some trials of the game, the avatar generated a predictive social cue that participants could use to anticipate the avatar's next play. We expected that wins on these cued trials would increase over the course of the task, even in the absence of explicit knowledge about the cue–outcome relationship. Finally, because evidence suggests that affective judgements (e.g., liking, trustworthiness) may relate to the predictability of behavior (Ames & Johar, 2009; Bayliss & Tipper, 2006; Capella, 1997), we expected that the degree to which participants experi-

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enced the avatar as predictable would relate to their ratings of how much they liked the avatar.

Methods

Participants

Forty psychology undergraduates participated in the experiment in exchange for partial course credit and a performance-based monetary bonus. We excluded five participants who did not believe the avatar was a genuine opponent (final $N = 35$; 21 female). Participants ranged from 18 to 25-years-old ($M = 20.63$, $SD = 1.90$).

Procedures

Participants were seated in front of a laptop computer with a built-in video camera. The computer was connected to a data port on the wall via a dummy Ethernet cable. Participants were told they would play a multiple-round game of rock–paper–scissors with an opponent who was in another room but would be visible in a window on the computer screen. They were also told that the video camera in their own computer would allow the opponent to see them throughout the experiment. After explaining the rules of the game and how to use the computer interface, the experimenter appeared to initialize the video link and left participants to play the game.

Each trial of the game had three phases (indicated by a colored frame around the avatar's image; Fig. 1A–C). In the first (2000–5000 ms), participants decided which play (rock, paper or scissors) they would make. In the second, participants indicated their move with a key press (500 ms). In the final phase, participants received feedback about trial outcome (3000–5000 ms).

Before beginning the game, the computer randomly chose one of two nonverbal cues (eyebrow or mouth movement; Fig. 1A) to be predictive of one of the avatar's three possible plays (e.g., the avatar might make an eyebrow movement before playing 'rock'). The cue occurred each time the avatar made the associated play and always occurred during the first trial phase, while participants chose their responses. After the first 10 trials of the game (in which no predictive cues were presented), participants played three, 75-trial blocks, each of which included 25 cued trials. Plays on the other 50 trials in each block were divided equally between the two non-cued plays. Play order was randomized. Wins were worth 10 pence, draws worth five pence and losses (including slow reaction times) worth minus 10 pence. Participants played 235 trials and received a performance-based bonus at the end of the game (range: £1–£6). The task, including the avatar (below), was programmed in Matlab (version 7.5; The MathWorks) using the Psychophysics Toolbox extensions (Brainard, 1997; Pelli, 1997) and presented on an MacBook Pro running OSX 10.5 (Apple Computers, Inc.).

After the game, participants completed a questionnaire assessing the degree to which they felt the opponent had played predictably (e.g., "I sometimes felt like I knew what my partner was going to play;" three items, $\alpha = 0.86$; 7-point Likert-scale: 1 = *Not at all*, 7 = *Extremely*) and how much they liked the opponent (e.g., "I liked my partner;" three items, $\alpha = 0.83$) and were debriefed. During debriefing, the experimenter assessed participants' beliefs about the task and whether they thought they had played a real opponent. After informing them that the opponent had been computer controlled, the experimenter asked whether the opponent had given any cues that allowed them to predict his behavior. Two participants reported the cue. The remaining participants were told about the cue, shown photographs of three possible cues (one predictive, one familiar but non-predictive, and one novel cue) and asked to identify the predictive cue. Because the computer randomly chose the predictive cue from among two of the cues depicted, the experimenter was blind to cue condition.

Avatar

The avatar was composed of a set of pre-recorded video-clips of a 22-year-old male that played continuously during the task (15 frames/s) such that the avatar's behavior resembled that of a person. There were three neutral clips (60 frames each); five blinks (4 frames each); 12 head movements (eight frames each); two genuine smiles (35 and 41 frames); three polite smiles (15 frames each); two frowns (15 frames each); two concentration displays (brow-lower, head forward, 14 and 21 frames); one interest display (brow-raise, lean forward, mouth movement; 21 frames); and one face-touch (hand to chin; 26 frames). The predictive cues (Fig. 1A) were either a brow-lower/squint (14 frames) or a lateral/downward movement of the mouth corners (14 frames). Only one of these cues was predictive. The other cue was allowed to occur during play in the first trial phase when participants were choosing their responses. All action clips started and ended with a neutral expression. A hidden Markov model governed transitions between clips. Neutral clips could begin at any frame and transitions from neutral to action could occur at any frame. However, action clips were required to begin at frame 1 and play completely to avoid discontinuities.

In order to ensure that the avatar was believable to participants, we needed to make his behavior appear as life-like as possible. To achieve this, we video-recorded two participants as they played a version of the game without the avatar (they saw a photo of an actor in a neutral pose) and based the transition parameters of our Markov model on data from these sessions. The majority of avatar actions consisted of behavioral "noise" (small head movements, blinks). Each action was controlled by a "state" parameter that indexed the avatar's likelihood of producing the movement. These probabilities were dynamically updated after each frame of video was presented and therefore changed over time. For instance, at the start of the task, the avatar had a low probability of blinking. This probability increased by a small amount (0.15%) at each successive video frame until the avatar blinked, at which point blink-probability reduced by a percentage of the current state (80%). Furthermore, changes in the avatar's probability of producing a movement depended on the task phase. For example, our pilot recordings indicated higher blink likelihood immediately after a response. To simulate this, blink-probability increased by a larger amount (0.25% per frame) during the 400–500 ms following the start of the response window. To simulate the reduced blink likelihood at feedback onset that we observed in pilot recordings, there was a 30% reduction in blink-probability at the onset of feedback. This led to an average blink rate of 11.39 blinks/min ($SD = 1.86$). All actions were similarly controlled by state parameters, although parameters adjusted differently depending on action type.

The probabilities of expressive movements (e.g., frowns and smiles) changed more slowly (across multiple trials). For example, the likelihood of smiling increased after feedback indicating the avatar had won, especially after a losing streak, and gradually decayed over time. Outcome relevant expressions (e.g., frowns, smiles) happened most often during the feedback phase in each trial. Other expressions (e.g., concentration, interest) occurred most often during the first trial phase when participants were deciding on their next play.

Results

As expected, a trial-type (cued, non-cued) × block (1, 2, 3) repeated-measures ANOVA examining win-frequency data showed a significant trial-type × block interaction such that as the task progressed, participants won significantly more often on cued, relative to non-cued trials, $F(2, 33) = 12.35$, $p = .001$; $\eta_p^2 = .28$.

It is often assumed that social cue information is processed unconsciously based on research in which cues are presented below participants' detection thresholds (e.g., Sweeny et al., 2009). However, the avatar's predictive cues were presented supraliminally (∼934 ms, from onset to offset). We therefore chose a stringent criterion to test the idea that cue-outcome learning could happen implicitly. Specifically, we assumed that all participants who correctly guessed the cue during debriefing ($N = 16$; ∼46%) had at least some knowledge of the contingency and we excluded them from further analyses. For the 19 participants who failed to identify the cue, a trial-type (cued, non-cued) × block (1, 2, 3) repeated-measures ANOVA showed the same result as our initial analysis. Specifically, this subset of participants won more often on cued, compared with non-cued trials as the task progressed (Fig. 1D; $F(2, 18) = 5.30$, $p = .01$; $\eta_p^2 = .23$). A one-sample t-test confirmed that by block 3, these participants were winning significantly more often than chance on cued trials, $t(18) = 2.54$, $p = .02$, Cohen's $d = 1.20$. Thus, explicit knowledge of the cue was not necessary for outcome prediction.

Participants who guessed the cue also showed improved win-rates on non-cued trials (Fig. 1D, left panel), $F(2, 30) = 3.61$,

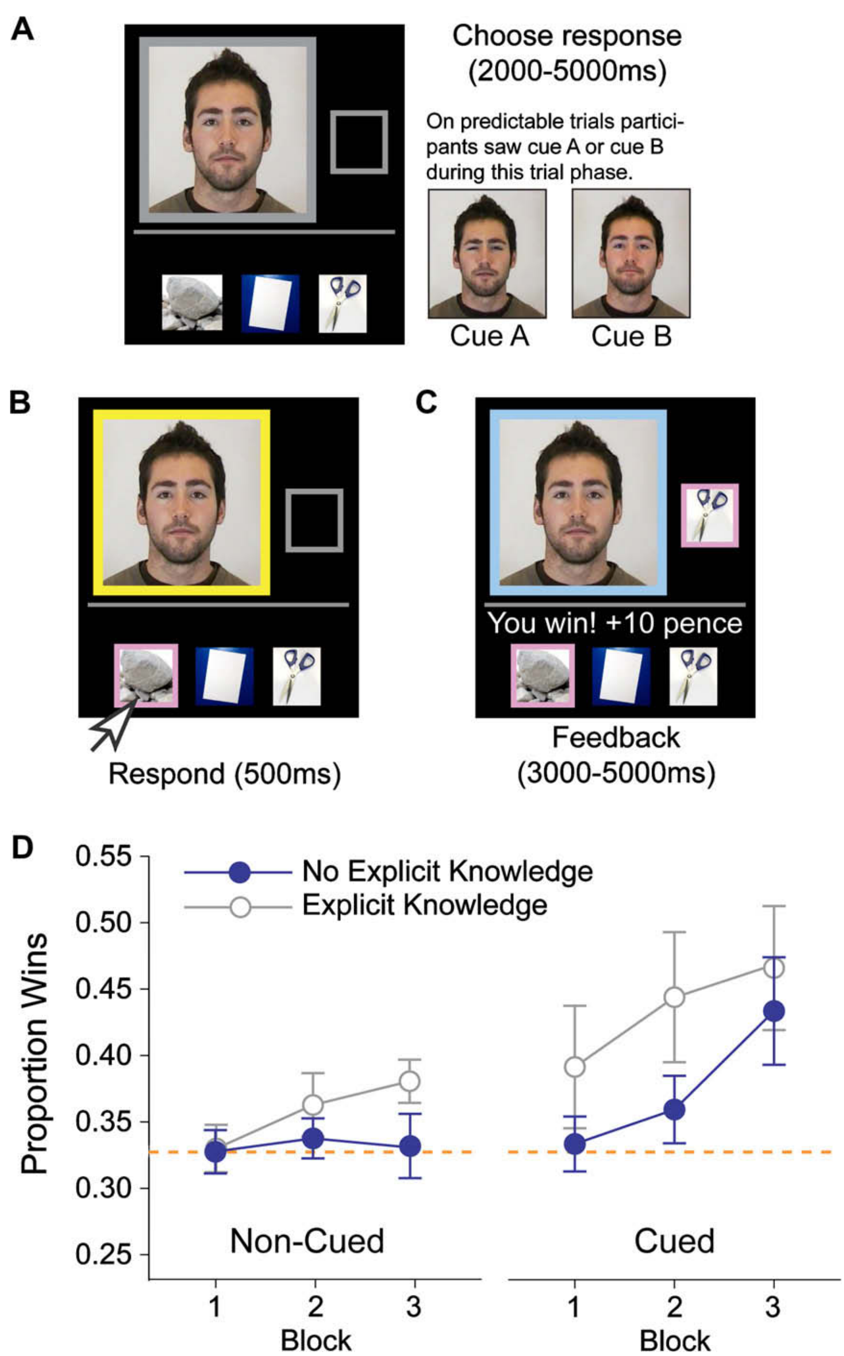

Fig. 1. Rock–paper–scissors task and results. (A) Decision-making phase. (B) Response phase. (C) Feedback phase. (D) Proportion of wins for participants with no explicit knowledge of the social cue (solid circles) and those with at least some explicit knowledge of the cue (open circles) by trial-type and block. The dashed line shows chance performance. Error bars show 1 standard error of the mean.

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$p = .04$; $\eta_p^2 = .19$. This implies that these participants may have been able to actively use their knowledge to rule out one response option on the non-cued trials, thereby increasing the odds of a correct guess. Interestingly, those who did not guess the cue showed no such effect, $F(2, 36) = .72$, $p = .49$; $\eta_p^2 = .04$. This suggests a qualitative difference in the degree to which participants used the cue. Specifically, those with explicit knowledge of the cue were able to use their knowledge flexibly in the absence of the cue whereas those without explicit knowledge were unable to do so. This difference in participants' ability to use the cue is consistent with numerous accounts of the distinction between explicit and implicit knowledge (e.g., Dienes & Perner, 2002; Tunney & Shanks, 2003).

Finally, we hypothesized that the degree to which participants without explicit knowledge experienced the avatar as predictable would relate to the degree to which they liked him. We obtained both subjective (''feelings" of predictability) and objective predictability measures (cued-trial win-rates), both of which correlated with liking (p-values < .02). We conducted mediational analyses to determine whether subjective or objective predictability measures accounted for the predictability-liking relationship. Objective win-rates mediated the relationship between subjective feelings of predictability and liking (Sobel Test = 2.45, $p = .01$). However, subjective feelings did not mediate the win-rate/liking relationship (Sobel Test = .98, $p = .33$). Thus, participants' objective ability to anticipate avatar behavior predicted their affective judgements.

Discussion

These results have important implications for understanding how people use social cues to navigate the social environment. We show that participants can use a partner's nonverbal cue to anticipate that partner's behavior, even in the absence of explicit knowledge of the cue–outcome relationship. This finding demonstrates that the subtle nonverbal signals people send can indeed serve as useful predictors of their future behavior, once cue-outcome contingencies are learned. This finding is important because unlike previous research, which focuses on meaningful, affectively valenced cues (e.g., Ekman, 2003; Kringelbach & Rolls, 2003; Krumhuber et al., 2007), this work shows that even fleeting (<1 s), previously meaningless cues can acquire meaning via associative learning mechanisms. More importantly, these cues can acquire value on a short timescale – within the space of a single interaction.

Does cue-outcome learning help people understand real social partners in face-to-face interactions? To our knowledge, there is no direct evidence for this idea, although naturalistic interaction studies show that the degree to which people reliably exchange social cues (e.g., smiles) affects perceptions of both an interaction and an interaction partner (Heerey & Kring, 2007). The mediation analysis in the present study suggests that the degree to which participants experienced the avatar as predictable increased how much they liked him. Although this result is consistent with previous research suggesting that more reliable displays improve interpersonal judgement accuracy (Funder & Colvin, 1988) and liking (Capella, 1997), it must be interpreted with caution as predictive cues in this study were deterministically associated with monetary rewards, unlike those in natural interaction.

Research shows that people can learn to predict a partner by observing partner behavior (Behrens, Hunt, & Rushworth, 2009; Behrens, Hunt, Woolrich, & Rushworth, 2008; Hampton, Bossaerts, & O'Doherty, 2008). Here we demonstrate the importance of subtle social cues in guiding this process by showing that people learn social cue–outcome relationships and use this knowledge to guide behavior, even in the absence of explicit knowledge of a social contingency. Although our avatar is only a proxy for a genuine interaction partner, the fact that participants believed they played another person, rather than a computer suggests that these findings will generalize to naturalistic settings with genuine partners, an idea we are currently exploring. Thus, these findings demonstrate that implicit associative learning mechanisms play a role in social interactions by allowing individuals to form and act on predictions about their interaction partners' behaviors.

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