Original Articles

Independent contribution of perceptual experience and social cognition to face recognition

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A R T I C L E   I N F O

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A B S T R A C T

Faces convey rich perceptual and social information. The contribution of perceptual and social information to face recognition has been typically examined in separate experiments. Here, we take a comprehensive approach by studying the contributions of both perceptual experience and social-conceptual information to face learning within the same experimental design. The effect of perceptual experience was examined by systematically varying the similarity between the learned and test face views. Social information was manipulated by asking participants to make social, perceptual, or no evaluations on faces during learning. Results show better recognition for the learned views, which declines as a function of the dissimilarity between the learned and unlearned views. Additionally, processing faces as social concepts produced a general gain in performance of a similar magnitude for both the learned and unlearned views. We concluded that both social-conceptual and perceptual information contribute to face recognition but through complementary, independent mechanisms. These findings highlight the importance of considering both cognition and perception to obtain comprehensive understanding of face recognition.

1. Introduction

Face recognition requires matching an incoming face stimulus to a representation of the face in memory. Recent studies have shown that our ability to match and recognize familiar faces is remarkable, in particular across different images of the same individual (for review see Young & Burton, 2017b, 2017a). What type of experience supports such superb recognition ability? During the process by which an unfamiliar face becomes familiar, we acquire rich perceptual experience with many different views, illuminations, and expressions of the learned identity. In addition, familiar faces are associated with a host of semantic (e.g., name, occupation), social (e.g., how friendly/dominant are they?), emotional (e.g., how much we like them), and episodic (e.g., when did we last see them?) information that determine their social relevance in current and future interactions. Nevertheless, the role of perceptual experience and social-conceptual information have mostly been studied separately with some studies primarily assessing the role of rich perceptual experience (Burton, Kramer, Ritchie, & Jenkins, 2016; Ritchie & Burton, 2017) and others assessing the role of social-cognitive factors in face recognition (Bernstein, Young, & Hugenberg, 2007; Van Bavel & Cunningham, 2012; Wilson, See, Bernstein, Hugenberg, & Chartier, 2014). Here, we attempt to provide a comprehensive account of face recognition by assessing the contributions of both perceptual experience and social-conceptual information in the process of becoming familiar with a new person (see also Schwartz & Yovel, 2016).

The important role of perceptual experience with different images of the same identity in face recognition has been demonstrated in studies that have shown that face recognition is relatively view-specific, such that learning a face from a given view does not generalize well to unlearned views (O’Toole, Edelman, & Bülthoff, 1998; Wallraven, Schwanganger, Schuhmacher, & Bülthoff, 2002). While some studies have used well-controlled images that systematically vary across head views and lighting (Duchaine & Nakayama, 2006; O’Toole et al., 1998; Troje & Kersten, 1999; Wallraven et al., 2002), more recent studies extended these findings with ambient stimuli that are more similar to our real-life experience with faces, highlighting the importance of experience with high variability of appearances of the same identity (Burton et al., 2016; Jenkins, White, Van Montfort, & Burton, 2011; Ritchie et al., 2015). Thus, both studies, which used controlled face stimuli and those that used more natural face stimuli indicate that transfer across different images of the same identity is relatively limited to images that are similar to the learned views. These studies indicate that the view-invariant representation found for familiar faces requires experience with a high variability of images of the familiar identity (Burton, 2013; Jenkins et al., 2011; Ritchie & Burton, 2017).

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In parallel to the perceptual experience that we get with faces during familiarization, we also acquire semantic, conceptual, and social information about them (Bruce & Young, 1986). Associating faces with socially-relevant information during learning have shown to improve face recognition. For example, learning faces with person-related labels (e.g., names, occupation) improved face recognition relative to faces without labels whereas no such effect was found for faces that were learned with person-unrelated labels (e.g., object names, symbols) (Schwartz & Yovel, 2016). This social-conceptual benefit in face recognition is also evident in studies that showed that social judgments about faces during learning (does the face look trustworthy/assertive?) improves face recognition relative to perceptual evaluations (is the face wide/symmetric?) (Winograd, 1976, 1981) or no evaluations (Schwartz & Yovel, in press). Such findings may be consistent with studies that revealed better recognition for faces that were associated with in-group information (e.g., same university, same personality of the participants) (Bernstein et al., 2007; Wilson, et al., 2014) or with expectations for future interactions with the learned faces (Wilson et al., 2014). Mechanisms that were proposed to account for these effects were increased attention, motivation, and individuation for socially-relevant faces (for review see Young, Hugenberg, Bernstein, & Sacco, 2012). The majority of these studies, however, primarily emphasized the effect of social information on discrimination and did not systematically examine the extent to which they generalized to new views of the learned faces, which has been the main focus of studies that examined the role of perceptual experience (Burton, 2013; Jenkins et al., 2011; Ritchie & Burton, 2017). To obtain a comprehensive understanding of the roles of both perceptual and social-conceptual experience in face recognition, it is important to examine them concurrently to assess the extent to which they contribute to face recognition independently or interactively.

In the current study, we examined the contributions of social relevance and perceptual experience to both discrimination among identities and generalization within identities. To make faces socially meaningful, participants made trait inferences about faces during the learning phase. The effect of social evaluations on face recognition was compared to two control conditions in which participants either made perceptual judgments about different facial features (e.g., face roundness, face symmetry) or made no evaluations about faces during learning (Schwartz & Yovel, in press). To assess the role of perceptual experience in face recognition, we systematically varied the similarity between the learned and the test face views by gradually increasing the angle difference between them. The recognition phase included four different views: some were identical to the images presented at the study and others were different (see Fig. 1). This design allowed us to concurrently compare the contributions of both perceptual experience and social cognition to face recognition from images that are either identical or gradually differing from the learned images and to examine the extent to which the contributions of perceptual experience and social inferences are independent. Based on previous studies that found that face recognition is view-specific, we predicted that performance for the learned views would be better than performance for the unlearned views and that it would decrease as the angle difference between the learned and the test images increases (O’Toole et al., 1998; Wallraven et al., 2002). Our main question was how the social-conceptual benefit in face recognition interacts with the similarity between the learned and test views. In particular, we assessed two possible outcomes: First, the contribution of social evaluations to face recognition is image specific to the learned views (Fig. 1, Left); Second, the contribution of social evaluations to face recognition is generalized to unlearned views (Fig. 1, Right). We examined these effects in different types of learning experience using either a single frontal face view (as shown in Fig. 1), multiple face views (multi-view) (Experiment 1, Fig. 2), or a single three-quarter (60°) face view (Experiment 2, Fig. 5). In all experiments during the recognition phase, we presented faces from four views: Frontal, 30°, 60°, and profile faces.

2. Experiment 1

2.1. Method and material

2.1.1. Participants

One hundred and twelve Caucasian participants were recruited online using the “panel4all” survey platform. Participants received $4 for 30 min. The participants were assigned to perform one of the two tasks: A total of 52 participants (26 females, between the ages 22–45, mean age = 30.5, SD = 5.5) performed the single-view task. One participant was excluded from the analysis as their reaction time for all the faces in one of the conditions (frontal view) were shorter than 200 ms, and were therefore excluded from analysis. Thus, 51 participants were included in the analysis of the single frontal-view task. A total of 60 participants (33 females, between the ages 21–45, mean age = 28, SD = 5.5) performed the multi-view task. Four participants were excluded from the analysis as their response times during the recognition phase were above/below the exclusion criteria in more than 40% of the trials. Thus, 56 participants were included in the analysis of the multi-view task. The study was approved by the ethics committee of Tel Aviv University, and all the participants gave their informed consent to participate in the study.

The number of participants was determined based on a similar study that we recently conducted, which revealed a robust benefit for social evaluations (ηp2 ∼ 0.50) on face recognition and included 25–30 subjects (Schwartz & Yovel, in press). Since the current study included four dependent variables within subjects and a comparison between two types of learning tasks (multi-view and single view), and therefore a larger number of statistical tests, we doubled the sample size to n = 50–60 for each experiment.

2.1.2. Stimuli

The stimuli were grayscale face photographs of 40 Caucasian young adult males, all taken from the Harvard Face Database (Duchaine & Nakayama, 2006). All face stimuli were of adult males with no glasses, facial hair, long hair, or scars. All photos were centered and their backgrounds were removed. From the pool of 40 identities, 24 identities were randomly assigned at the beginning of each experiment to be presented during the learning phase. The remaining 16 identities were novel faces: faces that appeared only in the recognition phase of the experiment. Thus, different identities were presented as old or novel faces to each participant. Of the 24 identities that were randomly assigned to each participant to be learned during the learning phase, 8 identities were randomly assigned to the social condition, 8 identities were assigned to the perceptual condition, and the other 8 identities were presented with no questions.

Two versions of the learning phase were presented to different groups of participants. In the single frontal view task, the same frontal face was presented five times for each identity. In the multi-view task, five different images of the same identity were presented: one in frontal view, two types of 30° view faces with two different types of lightings, and their mirror symmetric views (see Fig. 2). The recognition phase in both tasks was identical and presented profile, 60°, 30°, and frontal view faces with the same illumination like the frontal faces presented during the learning phase.

2.1.3. Procedure

2.1.3.1. Learning phase. During the learning phase, participants were asked to learn a total of 24 different identities and rate them based on either their perceptual appearance, their inferred personality traits, or to make no evaluations. Each trial began with either a perceptual or a social question from a set of five questions or with a blank screen with no questions. Social and perceptual mini-blocks of five questions were presented in a random order. Each question appeared on the screen for 3 s, followed by a 1 s inter-stimulus interval, after which a face was presented for 1 s. Following the face offset, a scale of 1–7 appeared on
the screen, and the participants were asked to rate the face on that scale based on the question. In the no evaluation condition, the screen remained blank for 3 s, followed by a presentation of a face for 1 s (Fig. 2).

The five perceptual or social questions were presented sequentially one after the other for each identity. Thus, each face was presented five times, once following each one of the five different questions. The order of the five questions on each mini-block was random. The five social questions were “How intelligent/dominant/trustworthy/friendly/aggressive does the face look?” The perceptual questions were “how symmetric/round/wide is the face?” or “how smooth/bright is the skin tone of the face?”

In the single frontal view task, the same frontal face was presented after each of the five questions. In the multi-view task, a different image of the same identity appeared after each of the five questions. The first image of each identity that was presented after the first question was

Fig. 1. The social-conceptual benefit in face recognition was examined for learned and unlearned face views. Faces were learned while making either social, perceptual, or no evaluations. This allowed us to assess whether the social-conceptual benefit (i.e., better recognition for socially evaluated faces) is view-specific (left) or whether it is generalized to unlearned views (right). The example above shows the two predictions for learned frontal faces (Experiment 1) and was also examined when learning multiple face views (Experiment 1) or a three-quarter (60°) face view (Experiment 2).

Fig. 2. Design of Experiment 1: Participants were either presented with faces from the same frontal view that repeated five times for each identity or with five different images from multiple views and lighting for each identity (a between-subjects factor). Twenty four identities were learned while making either social evaluations, perceptual evaluations, or no evaluations on the five different questions. The order of the five questions was random. The figure shows an example of one of the five evaluations that were made in each condition. During the test phase, the same identities and new identities were presented in four different views: frontal, 30°, 60°, and profile views, and participants were asked to determine which identity was presented in the learning phase (old) and which was new.
rotated 30° to the left. Following the second question, a second image of the same identity, which was also rotated 30° to the left, but with a different illumination was presented. Following the third question, a frontal image of a face was presented. The last two questions were each followed by mirror images of the first two faces now rotated 30° to the right, each with a different illumination (same illuminations as the first and second images). While the order of the questions was random, the presentation order of the images was fixed. A similar presentation was also used for the control faces that were presented with no questions. The same perceptual and social questions were used in the single-view and multi-view tasks.

2.1.3.2. Recognition phase. The recognition phase for the single-view and multi-view tasks was identical. Four different views of each of the 24 learned identities and 16 novel identities were presented. The test faces appeared sequentially in blocks by view: first, all the learned and novel identities were presented in a profile view one after the other in random order, followed by the identities presented in a 60° view, later by a 30° view, and finally with a frontal view. Participants were asked to decide whether each test image was of a new identity or a learned identity. Participants were informed that the same identities would repeat across the recognition phase in different views and that they should make an old response only for identities that appeared during the learning phase even if they are presented in a view that they have not seen before and to make a new response only for identities that did not appear in the learning phase.

2.2. Data analysis

Recognition Phase: Trials in which the response times were shorter than 200 ms or longer than 10 s were excluded from the analysis (less than 3% of trials). We computed the Hit rate (HR) and False alarm rate (FAR) during the old/new recognition task. Correct old responses for the learned identities were classified as Hits and incorrect old responses for new identities were classified as False Alarms. The dependent measure was [HR-FAR], which was separately calculated for the social, perceptual, and no evaluation conditions for each of the four test face views (90°, 60°, 30°, frontal). Note that the FAR is similar for the three evaluation conditions within each view. Whenever the sphericity assumption was violated, a Geisser–Greenhouse correction was applied.

Learning Phase: Reaction times were averaged across the five perceptual and five social evaluations during each participant’s learning phase. Trials in which the response times were shorter than 200 ms or longer than 10 s were excluded. The five participants that were excluded from the recognition phase (see Participants section) were also excluded from the analysis of the learning phase.

2.3. Results

2.3.1. Recognition phase

Fig. 3 shows performance level (HR-FAR) for the three types of evaluations and the four different test face views for faces learned from a single frontal view (left) and multi-views (right). We performed a mixed-ANOVA on recognition level [HR-FAR] with the Type of Evaluation (Social, Perceptual, No Evaluations) and Test face view (Frontal, 30°, 60°, Profile) as within-subject factors, and Learning view (Single view, Multi-view) as a between-subjects factor.

The results overall show better recognition following social than perceptual and no evaluation conditions with no difference between the perceptual and no evaluation conditions, as reflected in a main effect of Type of Evaluation F(2, 210) = 17.81, p < 0.001, η²p = 0.15. Pairwise comparisons corrected for three comparisons (p = 0.016) indicated that this advantage results from better recognition of the socially evaluated identities than both the perceptually evaluated (p < 0.001, Cohen’s d = 0.46) and the no evaluation faces (p < 0.001, Cohen’s d = 0.53). No difference was found between the perceptually evaluated faces and the no evaluation faces (p = 0.51, Cohen’s d = 0.06). In addition, we found that performance was better for the learned views than the non-learned views as reflected in a significant main effect of Test face view F(2, 277) = 15.96, p < 0.001, η²p = 0.013, (Greenhouse-Geisser sphericity correction). Pairwise comparisons corrected for six comparisons among 4 face views (p = 0.008) were applied. We found better recognition of the frontal test view than the 30° view (p = 0.002, Cohen’s d = 0.30), the 60° view (p < 0.001, Cohen’s d = 0.34) and the profile view (p < 0.001, Cohen’s d = 0.51), and better recognition of the 30° and the 60° test views than the profile test view (p < 0.001, Cohen’s d = 0.34, & p = 0.004, Cohen’s d = 0.28, respectively). No effect for Learning view was found, indicating overall similar performance for faces that were learned from a single or multiple views across the different test face views (F(1, 105) < 1). No interactions were found between the Learning view and Type of Evaluation (F(2, 210) < 1) between the Test face view and Type of Evaluation (F(6, 630) < 1), or Test face view, Type of Evaluation, and Learning view (F(6, 630) < 1), indicating a social evaluation benefit across all learning and test face view conditions. The absence of an interaction between the Type of evaluation and Learning view and/or Test view suggests that the effects of social evaluations and perceptual experience were independent.

A significant interaction was found between Learning view and Test face View F(3,315) = 5.82, p < 0.001, η²p = 0.05 (see Fig. 4). To further examine this interaction, performance for the different test views was examined for the two types of learning conditions. For these comparisons we used Bonferroni correction for six comparisons among four face views (p = 0.008). For the multi-view learning condition, we found no significant difference in performance among the frontal, 30°, 60° and profile view faces. In the single view learning condition, recognition was better for the frontal learned faces relative to the 30° view (p < 0.001, Cohen’s d = 0.59), the 60° view (p < 0.001, Cohen’s d = 0.82) and profile view (p < 0.001, Cohen’s d = 0.78) and for the 30° view than the profile view (p = 0.003, Cohen’s d = 0.43). An inspection of Fig. 4 also shows a numerically better performance for the frontal view faces following single than multi-view face learning, but not for the other views. However, post hoc tests corrected for four comparisons (p = 0.0125) revealed no significant difference between performance for each test view as a function of the study view (Frontal, p = 0.048, Cohen’s d = 0.38; 30° view, p = 0.66, Cohen’s d = 0.08; 60° view, p = 0.24, Cohen’s d = 0.25; Profile, p = 0.50, Cohen’s d = 0.13). Thus, we found no improvement in face recognition for any of the test face views following training with multiple views than training with a single view.

Table S1 presents the mean, standard deviation, and confidence intervals for HR for the three evaluation conditions and FAR for each of the four test views during the single-view and multi-view learning task.

2.3.2. Learning phase

During the learning phase, participants made social and perceptual evaluations on each of the five images of each identity. To examine whether better performance for the socially than perceptually evaluated faces was due to longer RT of the former, we compared the average reaction time for social and perceptual evaluations in the single-view and the multi-view conditions. In the single-view experiment, we found faster RT for social than perceptual evaluations t(50) = 3.87 , p < 0.001, Cohen’s d = 0.54. The same results were found in the multi-view experiment, t(55) = 2.42 , p = 0.018, Cohen’s d = 0.32. We, therefore, conclude that the social encoding benefit cannot be accounted for by a longer processing time of socially than perceptually evaluated faces during learning. Table S2 reports average, standard deviation and 95% confidence interval for RTs during the learning phase for social and perceptual evaluations.
2.4. Discussion

Our findings clearly show that both the perceptual similarity between the learned and test faces and making faces socially meaningful contribute to face recognition. Importantly, by studying the two effects in the same experimental design, we revealed that they contribute to face recognition in an independent, complementary manner. Consistent with previous studies, we found that face recognition is better for the learned than the unlearned views. Thus, performance following exposure to a single frontal view yielded better performance for the frontal than all the other views, and performance following exposure to multiple views yielded a more view-invariant representation. In addition to the contribution of perceptual experience, assigning social meaning to faces during learning improved face recognition. Interestingly, the magnitude of the social benefit in face recognition was similar for all face views, even for face views that were not presented during learning despite a decline in performance level for these unlearned views. This finding is intriguing as it suggests that some information about the appearance of the unlearned views is present but is not fully manifested for recognition of faces that have no social relevance. This social benefit in face recognition partly compensates for the lack of perceptual experience with a given face view. For example, in the single frontal view study performance for the unlearned, 30° or 60° views of the socially evaluated identities reached the level of performance for the learned frontal faces that were studied with perceptual or no evaluations (see Fig. 3). These findings show that social-conceptual and perceptual experience contribute to face recognition in different, complementary manners, therefore highlighting the importance of studying their concurrent effects on face recognition.

The findings that social evaluations improve face recognition relative to perceptual evaluations are consistent with studies that used a similar paradigm to study the effect of level of processing on face recognition (Bower & Karlin, 1974; Winograd, 1976). These studies attributed the social benefit to more elaborated processing of facial features during social than perceptual evaluations. Our data, however, show that reaction times during social evaluations were actually faster than during perceptual evaluations. These findings are consistent with our recent study that reports better recognition for socially evaluated faces despite shorter inspection time during learning (Schwartz & Yovel, in press). Thus, learning faces as social concepts is actually faster and more efficient than learning by judging their perceptual characteristics. These findings are also consistent with studies that showed better recognition for faces that were assigned to an ingroup relative to...
an outgroup category (Bernstein et al., 2007; Van Bavel & Cunningham, 2012) or to faces that were associated with labels indicating social power (Shriver & Hugenberg, 2010). These results therefore indicate that making faces socially relevant during learning improves face recognition (for review see Hugenberg, Young, Bernstein, & Sacco, 2010; Young et al., 2012). Our findings add to these studies by showing that the benefit of processing faces as social concepts is generalized to unlearned views. Thus, making faces socially relevant improves recognition of the learned identity rather than the learned face image, which is important for possible future interactions with socially relevant faces.

Recent studies have emphasized the importance of exposure to high variability of different images of the same individual for face recognition (Andrews, Jenkins, Cursiter, & Burton, 2015; Burton et al., 2016; Kramer, Manesi, Towler, Reynolds, & Burton, 2018; Ritchie & Burton, 2017). Our findings show that learning faces from multiple views (frontal and 30° views) relative to a single view (frontal) did not improve performance for any of the tested views. These findings may be inconsistent with a recent study with ambient faces that showed better recognition of identities that were learned from high variability than low variability images when the test images were different from the learned images (Ritchie & Burton, 2017, Experiment 1A). The advantage of exposure to high variability images was abolished; however, when the test faces were taken from the same movie used to create the low variability images (Ritchie & Burton, 2017, Experiment 1B) that were more similar to the low-variability than the high variability faces. Our study differs from these studies in using more controlled face images that may differ to a lesser degree but have the advantage that the variability among them can be better quantified. Future studies should further assess the effect of exposure to high and low variability with ambient faces as a function of the degree of similarity among the learned face images and between the study and test face images.

In Experiment 1, participants learned frontal view faces and showed better recognition for the learned frontal view than all other views and a similar social benefit for all test views. To replicate and extend these findings, we conducted a second experiment that was similar to the single frontal face view but presented the 60° single view faces in the learning phase. This allowed us to re-examine whether the social encoding benefit generates a general gain for both the learned and the unlearned views, as well as examine whether performance would be best for the learned view (60° view) and gradually decline as the difference between the learning and test-view angle increased. Based on the results from Experiment 1, we expected no interaction between the effects of social relevance and perceptual experience.

3. Experiment 2

3.1. Method and material

3.1.1. Participants

Fifty-nine participants (30 females, between the ages 18–43, mean age = 32.5, SD = 6.79) participated in Experiment 2, which was conducted online on the “panel4all” survey platform. All participants received payment for participating in the experiment ($4 for 30 min). The study was approved by the ethics committee of Tel Aviv University, and all participants gave their informed consent to participate in the study. One participant was excluded from analysis as more than 40% of their responses were above/below the RT exclusion criteria.

3.1.2. Procedure

The procedure was similar to the single view frontal face experiment in Experiment 1. The only difference was that 60° view faces were presented during the learning phase rather than frontal view faces. The rest of the design was identical and included the same experimental conditions in the learning and recognition phases as Experiment 1.

3.2. Data analysis

The data analysis was similar to Experiment 1. Less than 4% of the trials were excluded due to RTs shorter than 200 ms or longer than 10 s. When the sphericity assumption was violated, a Geisser–Greenhouse correction was applied.

3.3. Results

3.3.1. Recognition phase

Fig. 5 shows the recognition level (HR-FAR) for the three types of evaluations as a function of the face test view. A repeated measure ANOVA with Type of Evaluation and Test face views revealed a main effect of the type of evaluations, F(2, 114) = 17.51, p < 0.001, ηp² = 0.24, and a main effect of face test view, F(2.6, 148) = 26.65, p < 0.001, ηp² = 0.32 (Greenhouse-Geiser sphericity correction), but no interaction between the two factors, F(6, 342) < 1. Pairwise comparisons corrected for three comparisons (p = 0.016) showed better performance following social than perceptual evaluations (p < 0.001, Cohen’s d = 0.7) and social than no evaluations (p < 0.001, Cohen’s d = 0.72) but no difference in performance between identities presented with perceptual or no evaluations (p = 0.39, Cohen’s d = 0.11), replicating the results from Experiment 1. Furthermore, pairwise comparisons corrected for six comparisons (p = 0.008) revealed that performance was best for the learned 60° view faces when compared to the profile faces (p < 0.001, Cohen’s d = 0.72), 30° view faces (p < 0.001, Cohen’s d = 0.86), and frontal faces (p < 0.001, Cohen’s d = 0.95). The lowest performance was found for the frontal view that was the most distant from the learned 60° view when compared to the profile (p = 0.003, Cohen’s d = 0.41) and 30° view faces (p = 0.002, Cohen’s d = 0.42). There was no significant difference between recognition of the 30° view and the profile views (p = 0.82, Cohen’s d = 0.03), which were similarly close to the learned 60° view. Table S1 presents the mean, standard deviation, and confidence intervals for HR for the three evaluation conditions and FAR for each of the four test views in this experiment.

3.3.2. Learning phase

Reaction times were averaged across all five social evaluations and
all five perceptual evaluations across the different identities. A paired-sample t-test on RTs for making social and perceptual evaluations revealed significantly shorter RTs for social than perceptual evaluations, $t(57) = 2.5$, $p = 0.015$, Cohen's $d = 0.33$, replicating findings from Experiment 1. Table S2 reports average, standard deviation and 95% confidence interval for RT during the learning phase for social and perceptual evaluations.

3.4. Discussion

Results of Experiment 2 replicated and extended the results of Experiment 1 by showing best performance for the learned view, which declined as the angle between the learned and the test view increased. These findings again show that face recognition is view-selective and does not generalize well to new views that were not presented at learning. Nonetheless, the benefit of processing faces as social concepts for face recognition is found for all face views and is as large for the unlearned views as the learned-view faces. Taken together, the results of Experiments 1 and 2 show that what determines performance level in a face recognition task is both the perceptual similarity between the learned and test face images and the social relevance of the learned identities. Similar to the findings of Experiment 1, we see that making faces socially relevant during learning compensated for the lack of perceptual experience by increasing recognition for unlearned views (i.e., 30° and profile face view) to the level of recognition of learned view (60° face view) of identities that were encoded in a non-social context (i.e., perceptual or no evaluations) (see Fig. 5), as typically done in studies that examined only the effect of perceptual experience in face recognition.

4. General discussion

The goal of the current study was to examine the concurrent contribution of perceptual experience and social cognition to face recognition. These two factors are typically examined in separate experiments as vision scientists have been primarily interested in the role of perceptual experience in the generation of a view-invariant representation (e.g., O’Toole et al., 1998; Ritchie & Burton, 2017) and social/cognitive psychologists on the role of social cognition in our ability to discriminate among different identities (e.g., Bernstein et al., 2007; Van Bavel & Cunningham, 2012). The current design allowed us to examine both factors, which, in real-life, occur concurrently and assess their relative contribution to face recognition. Our findings clearly show that both perceptual experience and social cognition contribute to face recognition but they do that in complementary ways. Consistent with previous findings (Andrews et al., 2015; Burton et al., 2016; Ritchie & Burton, 2017), our study clearly shows that rich perceptual experience with variable images of the same individual is needed to obtain a stable, view-invariant representation. Our ability to generalize from a given view to unlearned views is relatively limited. However, even for faces for which we do get perceptual experience, face recognition does not reach its maximal aptitude if the faces are socially irrelevant. These findings indicate that in order to understand face recognition, faces should be studied as social concepts rather than purely perceptual stimuli (Hugenberg, Wilson, See, & Young, 2013; Schwartz & Yovel, 2016, in press). While the role of social attributes that are assigned to faces on face recognition has been investigated, these studies have primarily emphasized the role of individuation in discriminating between different identities (Hugenberg et al., 2010), while overlooking the importance of generalization across different images of the same individual.

The importance of experience with a high variability of images of the same identity for the generation of a view-invariant representation of face identity has been discussed recently (Burton et al., 2016; Jenkins & Burton, 2011; Kramer, Ritchie, & Burton, 2015). These studies have used naturally looking ambient faces that have the advantage of having greater and more natural variability than the controlled faces used in this study. Nevertheless, the controlled face stimuli used here allowed us to better quantify the degree of generalization from the learned to the test views as a function of their relative similarity (i.e., angle difference). Our findings show that performance significantly drops as the difference between the angle of the learned and test face views increases. This view-selective representation was reported in previous studies in the past several decades (O’Toole et al., 1998; Watson, Johnston, Hill, & Troje, 2005), indicating that generalization is limited to the learned views with some generalization to nearby similar views. Interestingly, however, when making faces socially relevant, performance improves even for views that were not presented during learning. Furthermore, the magnitude of this social-conceptual encoding benefit is similar for all test face views regardless of their degree of similarity to the learned view. Such benefit may be useful for future encounters with socially relevant faces in which we are likely to see a different appearance of the same identity.

Recent studies have shown that face matching for two images presented simultaneously is superior for familiar than unfamiliar faces. In particular, two different images of the same person may be classified as different identities for unfamiliar faces but can be easily classified as the same identity if the person is familiar (Jenkins et al., 2011; Ritchie et al., 2015). These findings suggest that the variability across different images of the same person can be as large as the variability among different identities and further highlights the importance of rich perceptual experience to obtain a view-invariant representation of familiar identities. The variability of the images that we used in the current study is more limited, and despite the view-specific recognition level, they could have been matched to the same identity if they were presented simultaneously. Future studies will determine the extent to which the social-conceptual benefit reported here is also generalized for images that are more dissimilar than those used in this study and assess the limits of this generalization. We recently proposed that one way in which such generalization across very different images of the same person is enabled for familiar but not for unfamiliar faces is by conceptual rather than perceptual matching (see Abudarham, Shkiller, & Yovel, 2019). Familiar faces are both learned and stored in association with conceptual labels, which can be used to link very different images to the same identity without the need to change their perceptual representations. We therefore predict that in order to obtain a perceptual benefit for images of the same identity that are perceptually dissimilar (i.e., high variability), faces need to be studied with labels that indicate their shared identity. This further emphasizes the importance of learning faces as concepts rather than pure percepts for the generation of a conceptual representation of a familiar face in memory.

In summary, our findings show that rich perceptual experience as well as making faces socially relevant both contribute to face recognition but through different mechanisms. Rich perceptual experience is needed for the generation of a view invariant representation of face identity as our ability to generalize across learned and unlearned views is quite poor. However, such rich perceptual experience with variable faces alone does not bring face recognition to its best aptitude. Our findings show that studying faces in a social context is more efficient and makes faces more memorable by providing them with social meaning. These two effects are independent as social meaning does not provide the needed experience with unknown face views and rich perceptual experience does not make faces socially meaningful. These findings emphasize the importance of studying face recognition from a more comprehensive perspective by considering the roles of emotional, social, and semantic information that are associated with faces as well as the perceptual experience with multiple images of the same individual that are needed to obtain a view-invariant representation that enables the superb recognition ability that humans have for familiar faces (Young & Burton, 2017a).