

The Roles of Perceptual and Conceptual Information in Face Recognition

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The representation of familiar objects is comprised of perceptual information about their visual properties as well as the conceptual knowledge that we have about them. What is the relative contribution of perceptual and conceptual information to object recognition? Here, we examined this question by designing a face familiarization protocol during which participants were either exposed to rich perceptual information (viewing each face in different angles and illuminations) or with conceptual information (associating each face with a different name). Both conditions were compared with single-view faces presented with no labels. Recognition was tested on new images of the same identities to assess whether learning generated a view-invariant representation. Results showed better recognition of novel images of the learned identities following association of a face with a name label, but no enhancement following exposure to multiple face views. Whereas these findings may be consistent with the role of category learning in object recognition, face recognition was better for labeled faces only when faces were associated with person-related labels (name, occupation), but not with person-unrelated labels (object names or symbols). These findings suggest that association of meaningful conceptual information with an image shifts its representation from an image-based percept to a view-invariant concept. They further indicate that the role of conceptual information should be considered to account for the superior recognition that we have for familiar faces and objects.

Keywords: object recognition, face recognition, category learning, perceptual learning

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Our ability to recognize real-world objects depends on the knowledge we acquire about them through experience. This knowledge includes their perceptual features such as their color or shape, as well as conceptual information such as their function, the category they belong to, or our attitudes toward them (Konkle, Brady, Alvarez, & Oliva, 2010a). For example, a banana is characterized by its unique curved shape and its yellow color, but it is also something we eat, that we like or dislike, and it has certain nutritious values. What is the relative contribution of the perceptual and conceptual information that we have about objects to object recognition? Because familiar objects are rich with both perceptual and conceptual information (Lupyan & Spivey, 2008), one way to isolate their different contributions is to study the learning process by which novel objects become familiar. During this learning process, we may either provide rich perceptual information by presenting the novel objects from different views or lighting or conceptual information by associating each novel ob-

ject with a unique label. Both types of learning have been shown to be effective (for review, see Palmeri & Gauthier, 2004). In particular, to examine the role of perceptual information, studies either present extensive perceptual exposure to different exemplars of the novel objects (e.g., Bülthoff & Edelman, 1992; Edelman & Bülthoff, 1992; Logothetis, Pauls, Bülthoff, & Poggio, 1994; Tarr, 1995; Tarr & Pinker, 1989) or associated unique labels to objects to encourage categorization or individuation (Gauthier & Tarr, 1997; Gauthier, Williams, Tarr, & Tanaka, 1998; Goldstone, 1994; Sigala & Logothetis, 2002). However, very few studies have attempted to directly compare the two types of learning protocols, as they typically involve very different task and stimulus manipulations. One such attempt was recently reported by Wong and colleagues (Y. K. Wong, Folstein, & Gauthier, 2012), who employed matched perceptual learning and category learning protocols in the same study and revealed that they generated different representations and brain activations for the learned novel objects.

In the current study, we attempt to compare the relative contribution of perceptual and conceptual information using the same paradigm with respect to faces. Similar to familiar objects, we have both very rich perceptual experience with familiar faces, as we have seen them from many different views, expressions, and illuminations, as well as rich conceptual information, including their name, occupation, or any other biographical or episodic information that we have about a familiar person. By studying the relative contribution of perceptual and conceptual information to face recognition, we hope to provide insights with respect to the superior ability that we have for identifying familiar faces. As will be further discussed matching, or recognition, of previously seen unfamiliar faces is prone to many errors, whereas recognition of

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familiar faces is remarkable (for reviews, see Hancock, Bruce, & Burton, 2000; Jenkins & Burton, 2011; R. A. Johnston & Edmonds, 2009). This is reflected in particular in our ability to recognize familiar faces across different images of the same person that may vary in illumination, pose, and expression (e.g., Jenkins, White, Van Montfort, & Burton, 2011). Understanding the relative contribution of perceptual and conceptual information to the invariant representation that we generate for faces will allow us to shed light on the mechanisms that underlie one of the most exceptional abilities of our visual recognition system: our ability to recognize familiar faces.

Recognition of Familiar and Unfamiliar Faces

Recent studies have emphasized that our ability to identify faces, in particular across different images of the same person, is significantly better for familiar than unfamiliar faces (for review, see Jenkins & Burton, 2011). A large body of studies reported convincing evidence that the identification of unfamiliar faces may be prone to many mistakes. A study by Bruce and colleagues (1999) found that the identification rate in a lineup task, in which participants are asked to determine whether a target face is present or absent in an array of photographs, was around 70% when faces were unfamiliar to the participants. Moreover, even easier tasks that do not involve a memory component such as matching between a living person and a photo, or matching of photos across different views or illuminations of the same person, yielded poor identification performance when the faces were unfamiliar to the participants (Bindemann & Sandford, 2011; Bruce, 1982; Burton, Wilson, Cowan, & Bruce, 1999; Henderson, Bruce, & Burton, 2001; Kemp, Towell, & Pike, 1997; Logie, Baddeley, & Woodhead, 1987; Megreya & Burton, 2008; White, Burton, & Kemp, 2016; White, Kemp, Jenkins, Matheson, & Burton, 2014). Indeed, a growing amount of evidence found that unfamiliar face recognition in matching or old–new memory tasks is greatly affected by changes in viewpoint, facial expression, and even superficial changes such as distance from camera or illumination (e.g., for review, see Hancock et al., 2000; also see Bruce, 1982; Burton et al., 2011; A. Johnston, Hill, & Carman, 1992; Longmore, Liu, & Young, 2008). These findings suggest that the representation of unfamiliar faces is image-specific (Bruce et al., 1999; Bruce, Henderson, Newman, & Burton, 2001; Longmore et al., 2008; Megreya & Burton, 2006, 2008) and based on superficial pictorial codes (Bruce et al., 2001; Hancock et al., 2000; R. A. Johnston & Edmonds, 2009).

In contrast to the vulnerable recognition abilities for unfamiliar faces, familiar face recognition is remarkably good. In particular, changes in facial expression, luminance, or pose that were found to severally impair recognition of unfamiliar faces hardly affect the recognition of familiar ones (Bruce, 1982). Moreover, familiar faces could be easily recognized only by their internal features, or only by their external features (Clutterbuck & Johnston, 2002, 2004, 2005; Ellis, Shepherd, & Davies, 1979; O'Donnell & Bruce, 2001; Young, 1984; Young, Hay, McWeeny, Flude, & Ellis, 1985), in very low resolution or degraded conditions (Burton, Bruce, & Hancock, 1999; Harmon, 1973; Sargent, 1986), and if stretched and compressed out of proportions (Hole, George, Eaves, & Rasek, 2002). These differences between the recognition abilities for familiar and unfamiliar faces give rise to the following

question: Because all familiar faces were once unfamiliar, what type of information do we acquire during the familiarization process that underlies the superior recognition that we have for familiar faces?

The Roles of Perceptual and Conceptual Information

One factor that has been hypothesized to play a major role in the superior recognition for familiar faces is the rich perceptual information that we acquire in the process of familiarization. In particular, Burton, Jenkins, and Schweinberger (2011) suggested that face familiarity is achieved after acquiring enough exemplars of a specific face in situations that present large in-person variability (e.g., by viewing many different photos that present a person from various viewpoints, lighting conditions, and so on). Because this hypothesis suggests that face familiarity depends on learning inner face variations (Benson & Perrett, 1993; Burton, Jenkins, Hancock, & White, 2005; Burton, Jenkins, & Schweinberger, 2011; Jenkins & Burton, 2008, 2011), it is expected that as the exposure to different photos increases, recognition rate of the face would also improve. Indeed, studies found that the amount of learned exemplars of a face is correlated with success in matching tasks (Bonner, Burton, & Bruce, 2003; Dowsett, Sandford, & Burton, 2016; White et al., 2014). Burton, Jenkins, and colleagues have further suggested that stable representations of familiar faces are made by averaging multiple photos into a single, abstract representation (Burton et al., 2005; Burton et al., 2011; Jenkins & Burton, 2008). This hypothesis was supported by findings that show better performance for averaged faces that are made of many different exemplars than faces that are made of fewer exemplars (Burton et al., 2005).

Although Burton and colleagues (2011) emphasized the role of rich perceptual information in familiar face recognition, familiar faces are rich not only in perceptual information but also in conceptual information, which is uniquely associated with each familiar face. Because in everyday life familiar faces are typically learned with additional conceptual information about them, such as their names, their occupations, and so on, conceptual information may improve the recognition of newly learned faces by mechanisms of categorization and individuation (Hugenberg, Young, Bernstein, & Sacco, 2010; Levin, 2000; McGugin, Tanaka, Lebrecht, Tarr, & Gauthier, 2011; Tanaka & Pierce, 2009). A set of studies by Tanaka and colleagues has shown that association of faces or objects with subordinate-level labels improved their later recognition (Gordon & Tanaka, 2011; Tanaka, Curran, & Sheinberg, 2005). At first, Tanaka et al. (2005) found that learning members of a group using specific subordinate-level labels (such as “snowy owl” for a bird) compared with basic family-level labels (such as “owl”) improved the discrimination between stimuli. In a later study, Tanaka and Pierce (2009) found that learning other-race faces using specific subordinate-level labels (such as by assigning a unique letter label to each face) compared with learning faces with family-level labels (such as by assigning the same letter label to all the faces in the same category) improved recognition performance of the individuated faces in a following recognition test (see also McGugin et al., 2011). Accordingly, Tanaka and colleagues (2005) suggested that perceptual categorization, rather than perceptual exposure, induces visual expertise and familiarization. As names are the subordinate-level labels for faces,

they should therefore play an important role in the process of individuation, which may facilitate discrimination between different faces (Gordon & Tanaka, 2011; Tanaka & Pierce, 2009). Whereas the role of individuation in face recognition has thus far been primarily used to explain the better recognition of own-race than other-race faces (Elliott, Wills, & Goldstein, 1973; Hugenberg et al., 2010; Levin, 2000), it may also account for the better recognition of familiar than unfamiliar faces.

Taken together, two possible factors could account for the improved identification ability of familiar over unfamiliar faces—rich perceptual and rich conceptual information (for a similar claim about familiar objects, see Konkle et al., 2010a; Lupyan & Spivey, 2008). Although both factors suggest possible explanations, they typically go together when an unfamiliar face becomes familiar, and it is therefore still unknown what may be the relative contribution of each of them to the superior recognition ability that we have for familiar faces. Thus, the initial goal of the current set of studies was to disentangle the roles of the perceptual and conceptual factors and directly compare their sole contribution during the process of face learning, using the same experimental design (Experiments 1 and 2). In Experiments 3 and 4, we further explored the enhancing effect that we found for conceptual information in Experiments 1 and 2.

Experiment 1: Exposure to Perceptual or Conceptual Information

The goal of this experiment was to directly compare the roles of perceptual and conceptual information on learning to recognize unfamiliar faces from new images of the learned identities. To that end, we used a between-subjects design that included two experimental groups—one group was exposed to faces learned from multiple views and lighting conditions to provide rich perceptual information, whereas the second group learned faces presented from a single view that were associated with unique conceptual information—a person name. Each subject was exposed to only one of the experimental conditions (perceptual or conceptual) to prevent any influences of one of the conditions on the other. To directly compare between these two experimental conditions, both groups were also presented with the same control condition single-view faces with no label. These faces served as a baseline for assessing the possible enhancing effect of presenting faces from multiple views relative to single-view faces (Multiview task) and for assessing the role of name labels relative to faces with no labels (Name task; see Figure 1).

To examine the role of rich perceptual information on the learning of novel faces, during the familiarization phase, 10 different images of each identity were presented from different views and lighting conditions (see Figure 1). By providing many exemplars for each identity, we provided a large variability within person images (Burton et al., 2005). If indeed perceptual exposure contributes to the generation of an optimal face representation in memory, we expect to see improved recognition performance following exposure to faces across different views and lighting relative to exposure to single-view faces.

To examine the role of conceptual information on the learning of novel faces, we associated a specific name to each identity (see Figure 1). As discussed above, names have been used to induce individuation in previous studies (Gordon & Tanaka, 2011; Tanaka

et al., 2005; Tanaka & Pierce, 2009; Yovel et al., 2012) and were suggested to play a key role in the formation and retrieval process of faces in memory (Gordon & Tanaka, 2011; Tanaka & Pierce, 2009). Accordingly, we predict that recognition of faces associated with conceptual information such as a name will be better than that of faces presented with no conceptual information.

Following the familiarization phase, we examined the recognition rate of faces using an old–new recognition test. During the recognition phase, both familiarized and novel face stimuli were presented sequentially, and participants were asked to discriminate the learned faces from the novel faces. Because generalization across changes in viewpoint and illuminations is a fundamental feature of familiar object and face recognition (Biederman & Gerhardstein, 1993; Jenkins & Burton, 2011; Logothetis et al., 1994; Poggio & Edelman, 1990), different images of the learned identities were presented during the test phase (see Figure 1). The presentation of faces that differed in view and lighting during the test phase ensured that recognition was not based on superficial pictorial codes (Bruce, 1982; Longmore et al., 2008; Megreya & Burton, 2006), but was generalized to new images of the same person, as typically found for the recognition of familiar faces (Burton, 2013).

Method

Participants. Participants were 30 healthy undergraduate and graduate students from Tel Aviv University (15 females between the ages of 18 and 27 years; $M_{\text{age}} = 23.25$, $SD = 2.48$). Fifteen participants were allocated to the multiview task and 15 to the name task. All participants received course credit or payment for participating in the experiment and reported normal or corrected-to-normal vision. The study was approved by the ethics committee of Tel Aviv University, and all participants gave informed consent to participate in the study.

Apparatus. Stimuli were presented using MATLAB Psychophysics Toolbox (R2010b; Brainard, 1997; Kleiner et al., 2007; Pelli, 1997) on a Samsung SyncMaster SA950 LCD monitor with a 100-Hz refresh rate. The monitor's contrast and brightness were set on 100%. The size of the face stimuli measured 300×300 pixels and occupied $6.87^\circ \times 6.87^\circ$ of visual angle on the monitor.

Stimuli. Stimuli were gray-scale photographs of 40 Caucasian young adult male faces, all taken from the Harvard face database (Tong & Nakayama, 1999). All photos were centered and their backgrounds were removed.

From the entire pool of 40 faces, 20 identities were randomly assigned for each participant to be the studied faces, that is, faces that would be learned during the familiarization phase. The other 20 identities were “novel faces”—face stimuli that would appear only during the recognition phase as novel, unseen faces. Thus, for each subject, a different set of face exemplars was used as old or new faces.

Of the 20 identities that were chosen at the beginning of each experiment to be learned during the familiarization phase, half were randomly assigned to be control faces, that is, faces that would be learned from a single view with no labels. The other 10 identities were experimental faces, that is, stimuli that appeared, each with a different name label (in the name experimental condition) or from various angles and lighting conditions (in the multiview experimental condition; see Figure 1). The association

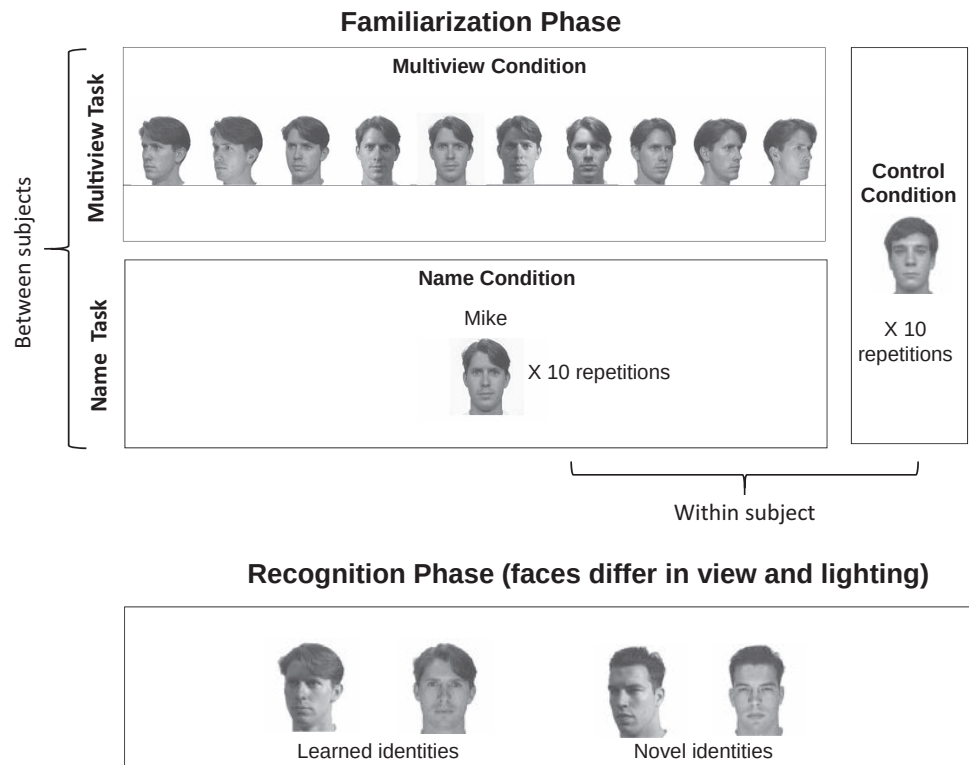


Figure 1. Two types of familiarization protocols were used in a between-subjects design. In the multiple-view task, face stimuli included 10 different images of each face presented in different views and/or illuminations (“multiview” experimental condition). Faces were presented in a random order and appeared once during the familiarization phase. In the name task, face stimuli were frontal images of faces presented with a name above them (“name” experimental condition). Each of the face-name pairs repeated 10 times for each identity to match the number or repetitions in the multiple-view condition. Control face stimuli were identical for the two tasks and included frontal faces presented without a label, repeated 10 times for each identity. Control faces were used as a within-subject baseline, to which performance of the multiview and name experimental conditions were compared. The recognition phases were identical in the two tasks and included two new images of each of the learned identities that differed from the learned images in lighting and/or view, as well as two images of 20 different novel identities.

of a given name label to a face exemplar was also random, such that each subject was presented with different exemplars of face–name association. The full list of names used in this experiment is presented in Table 5 (left column) of the online supplemental materials.

Procedure. The experiment consisted of a familiarization phase, which lasted about 10 min, followed by a recognition phase, which lasted about 4 min. At the beginning of the familiarization phase, participants were told that a series of faces would appear sequentially and were asked to memorize them the best they could for the recognition test that followed.

At the beginning of the “multiview” (perceptual) task, participants were told that some of the faces would appear in different views and lighting, and others would be shown multiple times from a single view. Participants were asked to memorize all faces. In the name (conceptual) task, participants were asked to memorize all faces and were told that some of the faces might appear with a name above them, and that in these cases, they were asked to learn both the face and the name presented above. Participants were informed that if a face appeared with a name label, the same

label would accompany the face during the entire familiarization phase. Participants were told before the recognition phase that during the test phase, different images of the same faces would be presented.

Familiarization phase. During the familiarization phase, participants viewed a series of photos of 20 different identities. The face stimuli were presented sequentially one after the other in a random order for a 1,000-ms exposure duration, with a 1,000-ms interstimulus interval. For each of the conditions, each face repeated 10 times throughout the familiarization session, resulting in a total of 10 s of exposure for each facial identity. A total of 20 facial identities were presented (half experimental, half control), resulting in a total of 200 photos (20 identities $\times$ 10 repetitions) that were viewed during the familiarization phase in a random order.

Recognition phase. The recognition phase was identical for the two tasks. During the subsequent recognition phase, participants performed an old–new recognition test—they were presented with a series of photos of 40 identities (20 learned identities and the 20 novel identities), presented sequentially, each for 1,000 ms,

in random order. For each facial identity, two different images were shown during the recognition phase, resulting in a total of 80 faces. The two images that were presented per identity differed in illumination from the studied images, one image was a three-quarter-view and one was a frontal-view face (see Figure 1). Participants were told that different images of the identities they saw during the study phase would be presented, and therefore they should attempt to recognize the identity of the face rather than the specific image that was presented during the familiarization stage. All of the face stimuli in the recognition phase appeared without a name (even if they were learned with a name during the familiarization phase).

Participants were asked to press one key if they thought that a specific face was one of the 20 learned identities, regardless of whether the faces were control or experimental stimuli, or a different key if they thought a face was not shown during the familiarization phase. After the participant made a response, the next trial commenced.

Data analysis. For all the experiments reported, we used two measures to estimate performance level on the task: The mean sensitivity (d') for discriminating between the old and novel faces and the averaged proportion of correct responses for old and new faces. Both measures revealed similar findings. We report statistical tests on the d' measures, and report in Table 1 the averaged d' and proportion correct scores for each experiment. Novel faces that were incorrectly identified as learned stimuli were considered false-alarm trials.

Results

Table 1 shows the d' and proportion of correct recognition for the different conditions. To compare the effect of the multiview and name tasks, a mixed ANOVA of d' , with Condition (control, experimental) as a within-subject factor and Task (name, multiview) as a between-subjects factor, was performed. The analysis revealed an interaction between Condition and Task, $F(1, 28) = 15.21, p = .001, \eta_p^2 = 0.35$.

Figure 2 shows the difference between performances for the multiview or name conditions compared with the control, single-view condition. Paired t tests showed that performance for faces presented with names was significantly higher than control faces, $t(14) = 2.99, p = .01$, Cohen's $d = 0.74$, whereas performance for faces presented in multiple views was lower than the control faces, $t(14) = 2.89, p = .01$, Cohen's $d = 0.75$.

We also examined whether the exposure to multiview or name faces had different effects on each of the two different face images that were presented during the recognition phase: the frontal- and three-quarter-view faces that differed in illumination from the

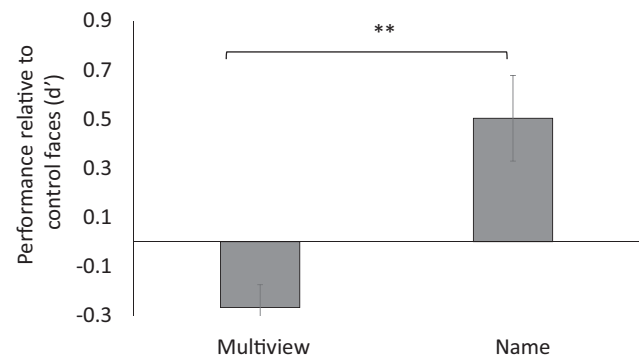


Figure 2. The difference between performance (d') in the multiview and name tasks relative to their control nonlabeled single-view face condition shows improvement in recognition performance for faces associated with names but not the multiview faces (see also Table 1). Error bars indicate the standard error of the difference between the experimental and control faces of each of the tasks. ** $p < .005$.

familiarization phase faces (see Table 1 of the online supplemental materials). We conducted a mixed ANOVA with Condition (experimental, control) and Face Type (different lighting, different view and lighting) as within-subject factors, and Task (multiview, name) as a between-subjects factor, and found a significant interaction between Task, Condition, and recognition of Face Type, $F(1, 28) = 5.25, p = .03, \eta_p^2 = 0.16$. This interaction was because of worse performance for multiview than control faces for faces that differed in lighting, $t(14) = 2.22, p = .04$, Cohen's $d = 0.57$, whereas no difference was found between the multiview and control faces for faces that differed in view and lighting. The enhancing effect of name did not differ between faces that differed in lighting or view, $t(14) = 1, p = 0.33$, Cohen's $d = 0.26$.

Discussion

In this experiment, we compared recognition of faces that were learned using either perceptual or conceptual information, and revealed two sets of findings. First, presenting faces across different views and lighting did not improve face recognition beyond presenting a face from a single view the same number of times. Second, we found better recognition for same-view faces that were associated with unique name labels than faces that were presented with no label. Importantly, face recognition was examined on new exemplars of the same identity, indicating that associating a name with a face facilitates an invariant identity representation across different illuminations and views.

The absence of an enhancing effect for faces that were presented from multiple views and lighting during learning may seem surprising at first, as it suggests that learning several views of a face, compared with a single view, does not result in better recognition performance of novel images of the same face. However, these results in fact replicate previous finding shown by Longmore and colleagues (2008), who found that exposure to various views of a face compared with a single view does not result in better recognition performance of a new view of the face during a following recognition task. One explanation suggested in that study was that each image of a face was learned individually and separately from

Table 1
Mean (Standard Deviation) of d' and Proportion Correct for the Experimental and Control Conditions in Experiment 1

Performance measures	Multiview task		Name task	
	Experimental	Control	Experimental	Control
d'	1.47 (.84)	1.73 (.88)	2.04 (.87)	1.54 (.85)
Proportion correct	.74 (.15)	.78 (.13)	.81 (.15)	.75 (.17)

the other images of the face, and so different images were not generalized into one coherent representation of the face during the learning phase. Similar findings were also reported by Pike, Kemp, Towell, and Phillips (1997), who presented multiple faces of the same identity one after the other so that there is no confusion that they belong to the same identity, and still found no difference between recognition of faces that were learned in multiple views versus a single view. Previous studies that did show better recognition following perceptual exposure (Malpass, Lavigneur, & Weldon, 1973, Experiment 2) differed from our study, as they presented the same images during the recognition phase that were shown during the familiarization phase. Therefore, the familiarization process left identical memory traces, and the recognition of the faces could have been mediated by superficial pictorial codes.

The lack of an enhancing effect for the multiview faces may result from the participants inability to link different views of a face presented during the familiarization phase to one person and generalize to new views of the same person. One way to enhance generalization of the different images to the same person is by associating each of the different faces of the same person with the same name. If, indeed, the lack of enhancing effect in the multiview task was because of difficulty in linking the different face views to the same person, we expect to find a significant improvement for multiview faces associated with names than for single-view faces associated with names, as those used in Experiment 1. However, if such an improvement would not be found, we can conclude that the amount of exposure to various views and lighting that we used in the current design does not improve face recognition relative to a single-view face, even when the different images are linked to the same person by a name label.

Experiment 2: Exposure to Perceptual and Conceptual Information

Whereas in Experiment 1 we isolated the roles of perceptual and conceptual information and examined their unique roles in familiarization processes, in this experiment, we combined the perceptual and conceptual information to examine their combined contribution relative to the sole contribution of each factor. In particular, we assessed whether providing both conceptual and perceptual information about faces would result in better recognition than providing either of them. To that end, we again ran the tasks that were used in Experiment 1 (multiview, name) and compared them with a new multiview-and-name task that examines the combined contribution of multiple views and names.

Another factor that we assessed in Experiment 2 is the ability to retrieve the names of named faces and its association with face recognition. Previous studies have shown that names are harder to recall compared with other types of conceptual information, such as occupation or nationality (Hay, Young, & Ellis, 1991; R. A. Johnston & Bruce, 1990; Yarmey, 1973; Young, Ellis, & Flude, 1988; Young, McWeeny, Ellis, & Hay, 1986). Accordingly, Bruce and Young's (1986) model suggested that successful name recollection is the last phase of recognition, following identification and retrieval of other semantic information. The model was later modified to suggest parallel retrieval processes for semantic information and names (Burton, Bruce, & Johnston, 1990), but still separates names from other types of semantic information. Name retrieval was therefore suggested to be relatively hard to recall

because the association between faces and names is arbitrary and unique (Semenza, Zettin, & Borgo, 1998). However, the enhancing effect of associating names with faces during encoding may be independent from our ability to retrieve the names themselves. In Experiment 2, we therefore reexamined the effect of name association on the later recognition of faces, and further assessed the rate at which the names of the learned faces was retrieved.

Method

Participants. Sixty undergraduate and graduate students from Tel Aviv University (41 females between the ages of 18 and 32 years; $M_{\text{age}} = 23.57$, $SD = 3.7$) participated in Experiment 2. All participants received course credit or payment for participating in the experiment. Twenty participants were allocated to each of the experimental conditions. All participants reported normal or corrected-to-normal vision, and gave informed consent to participate in the study, which was approved by the ethics committee of Tel Aviv University.

Apparatus. Stimuli were generated using JavaScript and were presented on a Samsung SyncMaster SA950 LCD monitor with a 100-Hz refresh rate. The monitor's contrast and brightness were set on 100%. The size of the face stimuli measured 300×300 pixels, leading to the size $6.87^\circ \times 6.87^\circ$ of visual angle.

Procedure. The stimuli and procedure of the familiarization and recognition phases of the experiment were identical to those described in Experiment 1 for the name and multiview tasks. In the multiview-and-name task, each experimental facial identity was presented across 10 different views, as with the multiview face, and was associated with a unique name label, as with the named faces. To compare this task with the other two tasks, we also included the same control condition of faces presented from a single view with no label attached. The effect of each of the experimental manipulations (multiple views, names, or the combination of the two) was examined as compared with the control condition of each task.

For the name and multiview-and-name tasks, we added a name retrieval phase following the face recognition phase. During the name retrieval phase, participants were presented with all the learned faces from the familiarization phase (both named and unnamed faces) sequentially. Each face appeared on the screen until the participants responded on whether it appeared with or without a name. If the participants thought that a face appeared with a name during the familiarization phase, they were asked to type the name that was associated with the relevant face. In case they could not retrieve the name, they were asked to indicate that they remembered that the face was learned with a name label but that they could not recall the name.

Results

Table 2 shows d' and proportion of correct responses for the different tasks and conditions. We first performed a mixed ANOVA to compare the sensitivity score (d') across the three tasks, with Condition (control, experimental) as a within-subject factor and Task (multi-view, name, multiview-and-name) as a between-subjects factor. We found a significant interaction between Condition and Task, $F(2, 57) = 4.89$, $p = .01$, $\eta_p^2 = 0.15$. Figure 3 shows the difference between performance in each of the exper-

Table 2
Mean (Standard Deviation) of d' and Proportion Correct for the Experimental and Control Conditions in Experiment 2

Performance measures	Multiview task		Name task		Multiview and name task	
	Experimental	Control	Experimental	Control	Experimental	Control
d'	1.9 (.12)	1.93 (.87)	2.42 (.73)	2.08 (.67)	2.43 (.6)	1.93 (.78)
Proportion correct	.79 (.16)	.8 (.14)	.86 (.11)	.82 (.13)	.87 (.08)	.79 (.15)

imental and control condition. Paired t tests showed that performance in the multiview-and-name condition was significantly better than the control nonlabeled faces, $t(19) = 3.64$, $p = .001$, Cohen's $d = 0.81$. Similar to the results of Experiment 1, performance in the name condition was significantly better than control nonlabeled faces, $t(19) = 3.63$, $p = .002$, Cohen's $d = 0.81$. Finally, performance in the multiview condition did not differ from control nonlabeled faces, $t(19) = 0.17$, $p = .87$, Cohen's $d = 0.04$.

To assess whether multiple-view faces facilitated recognition relative to single-view faces when both are associated with a name, we compared the multiview-and-name task with the single-view name task. A mixed ANOVA with Task (multiview-and-name, name) and Condition (experimental, control) revealed that the interaction between the name task and the multiview-and-name task was not significant, $F(1, 38) < 1$, $\eta_p^2 = 0.023$. The numerical difference in the average performance between the two tasks (see Figure 3) results from one subject that showed an improvement relative to control faces that was three standard deviations above the mean in the multiview-and-name task.

To assess the contribution of name labels to the recognition of multiview faces, we compared the multiview-and-name task with the multiview task. The mixed ANOVA revealed a significant interaction between the multiview and the multiview-and-name experimental conditions, $F(1, 38) = 7.76$, $p = .008$, $\eta_p^2 = 0.17$,

indicating better performance for named than nonlabeled faces, also for faces presented across different views.

We next examined whether the exposure to multiview or name faces had different effects on the two different face images we presented during the test session (different lighting, different view and lighting; see Table 2 of the online supplemental materials). A mixed ANOVA with Condition (experimental, control) and Face Type (different lighting, different view and lighting) as within-subject factors, and Task (multiview, name, multiview-and-name) as a between-subjects factor, revealed a main effect for Face Type, $F(1, 57) = 13.52$, $p = .001$, $\eta_p^2 = 0.19$, indicating an overall better performance for faces that differ only in lighting than for faces that also differed in view. Moreover, an interaction between Face Type and Condition was also found, $F(1, 57) = 27.28$, $p < .001$, $\eta_p^2 = 0.32$. This interaction reflects worse recognition of multiview than control faces for faces that differed in lighting, $t(19) = 4.68$, $p < .001$, Cohen's $d = 1.05$, whereas no difference was found between multiview and control faces for faces that differed in both view and lighting. Thus, for both types of test faces, we do not find that exposure to multiple-view images improved recognition. On the other hand, the enhancing effect of name labels was found both for faces that differed only in lighting and for faces that differed in both view and lighting, but was larger for the latter in the name condition, $t(19) = 1.9$, $p = .07$, Cohen's $d = 0.43$, and in the multiview-and-name condition, $t(19) = 2.68$, $p = 0.015$, Cohen's $d = 0.66$.

Finally, to verify that the results of Experiment 2 replicate the results of Experiment 1 and increase the power of the statistical analysis for the comparison of the name and the multiview conditions, we combined data from both experiments. Experiment (Experiment 1, Experiment 2) and Task (multiview, name) were used as between-subjects factors, and Condition (experimental, control) as a within-subject factor. Results show a significant interaction between the name and multiview tasks and condition (experimental, control), $F(1, 66) = 20.43$, $p < .001$, $\eta_p^2 = 0.24$, and no interaction between Task, Condition, and Experiment, $F(1, 66) = 2.59$, $p = .11$, $\eta_p^2 = 0.038$, indicating that the two experiments consistently revealed better recognition for the name than the multiview conditions.

Name Retrieval Phase

The data was collected from 40 subjects that performed the name and the multiview-and-name tasks. We computed the proportion of correct name recollection for the remembered faces. We found that name labels were retrieved on average for only 67% ($SD = 2.78\%$) and 58% ($SD = 1.69\%$) of the faces that were recognized during the recognition phases of the name task and the multiview-and-name tasks, respectively. There was no significant

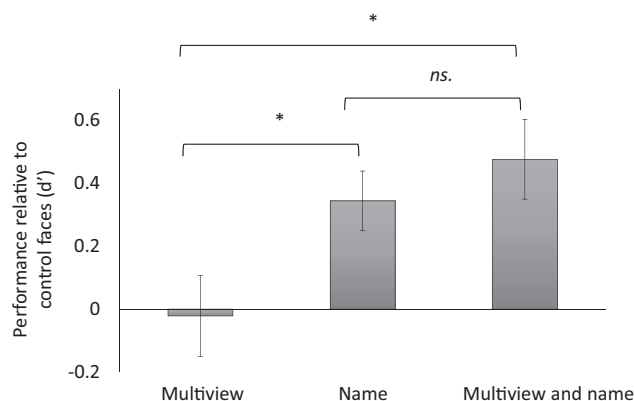


Figure 3. The difference between performance (d') for multiview faces presented without names (multiview), single-view faces presented with names (name), and multiview faces presented with names (multiview and name), relative to single-view faces presented with no labels (control faces; see also Table 2). Presentation of faces from multiple views with a name did not improve face recognition relative to single-view presentation with names. Both conditions of named faces enhanced recognition relative to faces presented without names. Error bars indicate the standard error of the difference between the experimental and control faces. * $p < .05$.

difference between the proportion of name retrieval between the two tasks, $t(38) = 1.27$, $p = .21$, Cohen's $d = 0.39$. The relatively low proportion of name retrieval is consistent with previous studies that showed difficulties in retrieving names of familiar/familiarized faces (Hay et al., 1991; James, 2004; R. A. Johnston & Bruce, 1990; McWeeny, Young, Hay, & Ellis, 1987; Yarmey, 1973; Young et al., 1986, 1988) and will be further examined and discussed in Experiment 4.

Discussion

Experiment 2 revealed two interesting findings. First, recognition of faces that were learned from multiple views with name labels did not differ from recognition of faces that were learned with name labels from a single view. Second, both name conditions yielded better face recognition than exposure to multiple-view faces with no name labels. These findings are both replicating and extending the results reported in Experiment 1, by showing no enhancing effect for the multiview condition beyond the name label effect. The fact that name labels associated with multiple-view faces generated better performance than multiple-view faces with no labels suggests that name labels may link the different images to a common view-invariant representation.

The absence of an enhancing effect in the multiple-view condition may be inconsistent with Burton and Jenkins's suggestion that familiar faces benefit from exposure to within-person variability in face images (Andrews, Jenkins, Cursiter, & Burton, 2015; Burton et al., 2005; Burton, Kramer, Ritchie, & Jenkins, 2016; Jenkins & Burton, 2011). They may also be inconsistent with the many perceptual learning paradigms used with objects, which do show better performance and more invariant representation for novel objects following perceptual training (e.g., Bülthoff & Edelman, 1992; de Beeck, Wagemans, & Vogels, 2003; Edelman & Bülthoff, 1992; Logothetis et al., 1994; Tarr, 1995). However, it is possible that the number of different images we presented in this study is not sufficient to generate the stable representation that we acquire for familiar faces and that additional exposure was needed. Furthermore, it is possible that the faces were not presented for a sufficient exposure duration in our experiment. Most perceptual learning paradigms include many more repetitions of the familiarized stimuli and training lasts for much longer than the 10 min of familiarization session that we used in our task. Finally, even though the face stimuli in our experiment were presented from various views and lighting conditions, all the images were taken using the same camera and during the same day, and it is likely that a wider and more variable sample of photos could have improved the generalization and overall recognition of the faces. Indeed, a recent study by Murphy, Ipser, Gaigg, and Cook (2015) assessed the role of variability of face exemplars by using a large set of 96 exemplars for each of the eight identities used in the study, and found improved face recognition of these faces relative to a smaller number of six repeating exemplars of a face. Moreover, this study presented each identity for a total of 96 s, which is much longer than the total of 10 s presentation of each identity used in our study. Importantly, however, the same amount of possibly limited exposure that we used in our multiview task was enough to facilitate recognition for faces that were presented from a single view with names. Moreover, learning faces associated with name labels allowed better recognition of these identities presented from

different views and lighting. These findings suggest that the role of conceptual information in face recognition should be considered; therefore, for the rest of this article, we further explore this effect. Nevertheless, our data cannot discount the possible role of perceptual information, but suggest that it may require more extensive exposure than the one provided in our familiarization protocol.

The enhanced face recognition that we found for faces associated with name labels is consistent with many previous studies that used labels during face and object learning tasks (Eley, 1982; Gauthier, Anderson, Tarr, Skudlarski, & Gore, 1997; Gauthier & Tarr, 1997; Gauthier et al., 1998; Gordon & Tanaka, 2011; McGugin et al., 2011; Tanaka et al., 2005; A. C. N. Wong, Palmeri, & Gauthier, 2009). A study by Gauthier James, Curby, and Tarr (2003) found that associating novel objects with semantically dissimilar concepts resulted in better performance in matching judgments than associating objects with semantically similar concepts. A study by Xu (2002) found that even 9-month-old infants better recognize labeled than nonlabeled objects. These findings are consistent with many other category learning studies showing that associating objects with different labels/categories improves the recognition or discrimination between them (de Beeck, et al., 2003; Eley, 1982; Gauthier & Tarr, 1997; Gauthier et al., 1998; Goldstone, 1994). Another example is a study by Lupyan, Rakison, and McClelland (2007) that examined object recognition for labeled versus nonlabeled novel objects. During the training phase, novel objects were either associated with meaningless labels or were shown without labels. Performance, both during the training (for the trained objects) and during the test phase (for novel exemplars of the trained categories), was better for the labeled than the nonlabeled objects. The authors suggested that labels enhance the visual representation of learned stimuli by top-down processes. It is noteworthy that the faces we presented during the recognition phase were different images of the familiarized faces, therefore suggesting that association of conceptual information generated a view-invariant representation rather than an image-based representation of these faces. These findings are consistent with a study by Curby, Hayward, and Gauthier (2004), who found that learning novel objects using semantic associations resulted in reduced viewpoint dependence, thus suggesting that conceptual information contributes to the formation of view-invariant representation of familiarized objects.

What mechanisms may underlie the enhanced recognition for the name labeled than nonlabeled faces? We consider three possible mechanisms that may not be mutually exclusive: attention, individuation (Gordon & Tanaka, 2011; Levin, 2000; McGugin et al., 2011; Tanaka & Pierce, 2009), and a representational shift from a percept to a concept (Lupyan & Spivey, 2008). According to an attentional account, labeled faces are better recognized because during the familiarization phase, participants are asked to memorize both the label and the face, whereas only faces are memorized for nonlabeled faces. Thus, participants are more engaged with the labeled than nonlabeled faces. However, as mentioned above, several studies found that unique, subordinate labels enhanced face and object recognition relative to exposure to the same objects or faces with similar superordinate labels (Tanaka et al., 2005; Tanaka & Pierce, 2009; see also Levin, 2000). In these cases, despite the fact that all images were associated with labels, performance was better for stimuli that were associated with unique labels but not when they were presented with a similar

label. These findings are consistent with the many category learning studies mentioned above (Gauthier et al., 2003; Gauthier & Tarr, 1997; Gauthier et al., 1998; Goldstone, 1994, 1998; Goldstone, Lippa, & Shiffrin, 2001; Goldstone & Styvers, 2001), and suggest that it is the process of individuation that enhances recognition for faces that are associated with unique labels. The process of individuation involves attending to identity diagnostic characteristics, which enhance discrimination between different faces (for review, see Hugenberg et al., 2010). This mechanism, however, emphasizes the ability to discriminate among the different learned identities, whereas our findings here show that labels may also enhance the generalization across different images of the same face. To account for this effect, we suggest a third mechanism, according to which association of conceptually relevant information to an image shifts its representation from an image-based percept to a view-invariant concept. According to this hypothesis, only conceptually relevant labels will shift a face representation from a view-specific percept to a view-invariant concept. In contrast, attention or individuation mechanisms predict that association of any unique label with a face will enhance recognition relative to nonlabeled faces or same-labeled faces.

To test this prediction, in Experiment 3, we used labels, which, unlike names, are not typically associated with faces. If we find that faces that were learned with person-unrelated labels are better recognized than nonlabeled faces, attention or individuation may indeed be the relevant mechanisms that account for the improved face recognition that we found for named faces. However, if faces with person-unrelated labels are not better recognized than nonlabeled faces, then attention or individuation mechanisms alone cannot account for our findings in Experiments 1 and 2.

Experiment 3: The Role of Conceptually Unrelated Labels in Face Recognition

To assess whether labels that are not typically associated with faces may enhance face recognition as much as names did, in Experiment 3, we used two different types of labels. For one group of participants, we used Symbols such as ***** or %%%%%%%%% as labels (see Table 5 of the online supplemental materials). Similar to people names, symbols provide no information about the visual properties of the face, but unlike names, they are not typically associated with faces. Because each of these labels was associated with a different face, and was different and unique, symbols qualify as subordinate-level labels and are expected to induce individuation (Levin, 2000; Tanaka et al., 2005). However, symbols contain minimal semantic information that may be harder to encode or associate with faces. We therefore tested a second group of participants that learned faces with object names, such as “chair” and “key,” as labels. Object names were used because they contain more accessible semantic information than symbols and may be easier to encode. Because faces are typically not associated with either symbols or object names, this experiment allowed us to test whether the association of faces with unique labels that are not typically associated with faces may enhance face recognition as the name labels did.

Method

Participants. Twenty-nine undergraduate and graduate students from Tel Aviv University participated in the experiment.

Fifteen subjects participated in the “symbol” label experiment (eight females between the ages of 18 and 23 years, $M_{\text{age}} = 20.63$, $SD = 1.7$) and 14 participants participated in the “object name” label experiment (eight females, between the ages of 21 and 28, $M_{\text{age}} = 24$, $SD = 2.23$). All participants received course credit or payment for participating in the experiment and reported normal or corrected-to-normal vision. The study was approved by the ethics committee of Tel Aviv University, and all participants gave informed consent to participate in the study.

Stimuli. The same face stimuli that were used in Experiments 1 and 2 were used in this experiment. Similar to the name task, 10 of the faces in the symbol and in the object-name tasks were presented with 10 unique labels above them, and 10 faces were presented with no labels. The full list of labels used in Experiment 3 is presented in Table 5 of the online supplemental materials (second and third left columns). All faces in the study phase were presented in a frontal view. In the test phase, we used the same stimuli that were presented in Experiments 1 and 2 that differed from the familiarized faces in lighting and view.

Procedure. The procedure of the familiarization and recognition phases was identical to the name task in Experiment 1, but instead of name labels, faces were associated with 10 different symbols to one group of participants or 10 different object names to another group of participants.

Results

Table 3 shows the proportion of correct responses and d' of the labeled and nonlabeled faces in Experiment 3. A paired t test of d' for the symbol-labeled and nonlabeled faces revealed no difference between the two conditions, $t(14) = 0.64$, $p = .52$, Cohen's $d = 0.167$, thus suggesting that symbol labels did not enhance recognition of faces relative to nonlabeled faces. A paired t test of d' for the object-name-labeled faces and the nonlabeled faces also revealed no difference in performance, $t(13) = 0.48$, $p = .64$, Cohen's $d = 0.13$, thus suggesting that object name did not enhance recognition of faces relative to nonlabeled faces.

To compare the effect of symbol labels with name labels (Experiment 1), a mixed ANOVA of d' , with Condition (label, nonlabeled) as a within subject factor and Label Type (name, symbol) as a between-subjects factor, was performed. The analysis revealed a significant interaction between these factors, $F(1, 28) = 6.37$, $p = .018$, $\eta_p^2 = 0.19$, indicating improved performance for the name-labeled faces but not for symbol-labeled faces, compared with their nonlabeled faces (see Figure 4). To compare the effect of object labels with name labels (Experiment 1), a mixed ANOVA of d' , with Condition (label, nonlabeled) as a within-subject factor and Label Type (name, object name) as a between-

Table 3
Mean (Standard Deviation) of d' and Proportion Correct for the Labeled and Nonlabeled Faces in Experiment 3

Performance measures	Symbol task		Object name task	
	Symbol	No label	Object name	No label
d'	1.80 (.92)	1.91 (.92)	2.02 (.7)	1.96 (.92)
Proportion correct	.78 (.14)	.78 (.16)	.79 (.14)	.79 (.17)

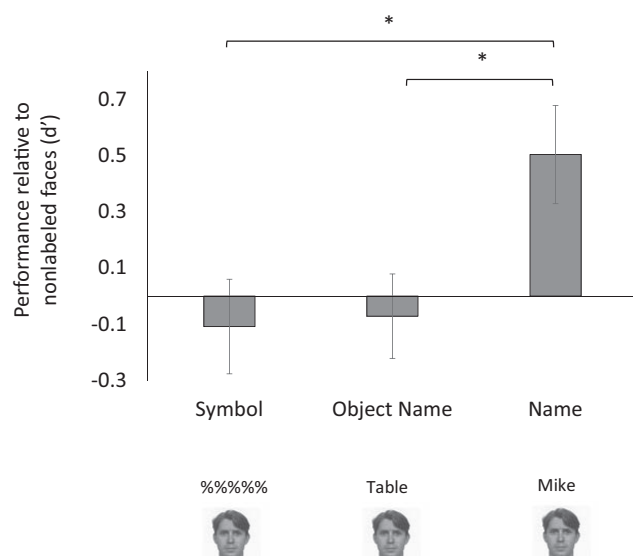


Figure 4. The difference between performance (d') for labeled and nonlabeled faces in the symbol and object name tasks compared with the name task (Experiment 1) show that unlike names, person-unrelated labels did not enhance face recognition relative to nonlabeled faces (see also Table 3). Error bars indicate the standard error of the difference between the label and the nonlabeled faces of each of the label types. * $p < .05$.

subjects factor, was performed. A significant interaction between these factors was found, $F(1, 27) = 6.1$, $p = .02$, $\eta_p^2 = 0.19$, indicating improved performance for the name-labeled faces but not the object-name labels, compared with their control nonlabeled faces.

Finally, in order to assess the contribution of each of the tasks to the recognition of faces of different lighting and different views (see Table 3 of the online supplemental materials), we conducted a mixed ANOVA with Condition (label, nonlabeled) and Face Type (different lighting, different view and lighting) as within-subject factors and Label Type (name, symbol, object name) as a between-subjects factor. Analysis revealed a main effect for Face Type, $F(1, 41) = 25.71$, $p < .001$, $\eta_p^2 = 0.39$, indicating an overall better performance for faces that differed in lighting than for faces that differed in both view and lighting. No interaction was found between Face Type and Condition, $F(2, 41) = 29.79$, $F < 1$, $\eta_p^2 = 0.04$, or between Face Type, Condition, and Label Type, indicating that the enhancing effect found for people names, but not for symbols or object names, was similar both for faces that differ in lighting and faces that differ in view and lighting from the learned faces.

Discussion

In Experiment 3, we used symbols or object names as a set of uninformative, but unique, labels that are not typically associated with faces to induce individuation to the learned faces without providing person-related conceptual information. Our results show no difference in face recognition between labeled and nonlabeled faces when symbols and object names are used as labels. These findings suggest that attention and individuation alone may not account for the enhanced recognition that we found for name-

labeled faces, because based on these mechanisms, any unique label associated with faces should improve face recognition for the labeled than nonlabeled faces. Instead, our data show that not all labels enhance recognition similarly. In particular, labels that are not typically associated with faces, such as symbols or object names, do not enhance face recognition compared with person-name labels. What may therefore account for the enhanced recognition that we revealed for faces associated with name labels?

As mentioned above, the motivation to use unfamiliar faces or novel objects to study the roles of perceptual and conceptual information in recognition is that they lack previous perceptual and conceptual experience, and therefore the role of each of them can be separately examined. Previous studies that associated arbitrary labels with novel objects did find that the labels enhanced recognition of novel objects (e.g., Lupyan et al., 2007). However, unlike novel objects, which can be equally associated with any sort of information, unfamiliar faces are already associated with person-related conceptual information, such as a person name or occupation, and less so with person-unrelated labels, such as symbols and object names. If the enhancing effect of labels on recognition reflects a shift in the representation from an image-based percept to a view-invariant concept, then any labels that are conceptually associated with their percepts will improve recognition relative to labels that are not typically associated with them. Thus, in Experiment 4, we assessed the role of other types of person-related labels on face recognition and directly compared them with person-unrelated labels.

Experiment 4: The Role of Conceptually Related Labels in Face Recognition

To test whether the enhanced recognition for faces associated with people names is unique to name labels or may extend to any person-related labels, we used two types of person-related labels. First, we examined whether any names, even if they are incongruent with the faces, would enhance face recognition. To that effect, we used female names as labels and associated a different female name to each of the male faces. If the mere association of a face with a name (a unique person-related label) is enough to improve face recognition, then gender-inconsistent names would improve the recognition of faces as much as gender-consistent names. However, if this enhancement occurs only for person-related information that is semantically consistent with a face, inconsistent name labels would not enhance recognition of faces.

The second person-related condition we used was meant to reveal whether any congruent person-related conceptual information associated with faces would result in better recognition of these faces, or whether the effect is unique to people names. To that end, we chose to use occupations as labels, as occupations consist of congruent person-related information, which is often associated with faces. Previous studies have also found that occupations are retrieved faster and more accurately than people names (Hay et al., 1991; James, 2004; R. A. Johnston & Bruce, 1990; McWeeny et al., 1987; Yarmey, 1973; Young et al., 1986, 1988), thus suggesting that they can be easily associated with faces. Therefore, in this experiment, we associated each face with a unique occupation label, such as “lawyer” or “programmer” (see Table 5 of the online supplemental materials).

To provide a full account of the effects of person-related and nonrelated labels, in addition to the gender-inconsistent and occupation labels, we again used the labels that were previously examined in Experiment 3 and assigned participants randomly to each of the four different tasks (symbol, object name, female name, and occupation). This allowed us to both replicate Experiment 3 and directly compare the effect of person-unrelated labels with person-related labels on face recognition.

Finally, in Experiment 4, we also tested the accuracy of label retrieval. In particular, we were interested in assessing whether labels that improve face recognition would also be recalled more easily during the label retrieval phase. Previous studies have shown that occupations are better recalled than names both for famous faces and when studied in association with unfamiliar faces (R. A. Johnston & Bruce, 1990; Young et al., 1986, 1988). However, these studies did not assess the effect of name and occupation labels on face recognition, but on label retrieval. In this study, we examined the effect of different labels on face recognition and then examined the retrieval of the labels associated with each face to assess whether labels that enhance face recognition are also easier to retrieve than labels that do not enhance face recognition, or whether the two processes are independent.

Method

Participants. Participants were 120 healthy undergraduate and graduate students from Tel Aviv University (92 females between the ages of 18 and 45 years, $M_{\text{age}} = 23.25$, $SD = 3.57$). All participants received course credit or payment for participating in the experiment and reported normal or corrected-to-normal vision. The study was approved by the ethics committee of Tel Aviv University, and all participants gave informed consent to participate in the study.

Participants were randomly allocated to perform one of the four different tasks (symbol, object name, female name, or occupation), so that a total of 30 participants completed each of the tasks. Each participant performed only one task, to avoid any possible influences across tasks. Each task measured the recognition level of labeled and nonlabeled face stimuli. To compare performance in these tasks to performance in the gender-consistent name task (Experiment 2), we ran 13 additional subjects (10 females, between the ages of 21 and 28, $M_{\text{age}} = 23.69$, $SD = 2.14$) on the same name task we ran in Experiment 2 and measured performance level on this larger sample of 33 participants.

Apparatus. Stimuli were generated using JavaScript and were presented on a Samsung SyncMaster SA950 LCD monitor with a 100-Hz refresh rate. The monitor's contrast and brightness were set on 100%. The size of the face stimuli measured 300×300 pixels, leading to the size $6.87^\circ \times 6.87^\circ$ of visual angle.

Procedure. The stimuli and procedure of the familiarization and recognition phases of the experiment were identical to the previous experiments. In addition to the face recognition task, we also included a label retrieval task at the end of each recognition task (identical to the one used in Experiment 2). The retrieval task was used to examine whether labels that enhance face recognition are also better remembered or whether these two effects are independent.

Results

Table 4 shows the proportion of correct responses and d' across the different tasks and conditions. We first performed a mixed ANOVA with Condition (labeled, nonlabeled) as a within-subject factor and Label Type (symbol, object name, female name, occupation, male name) as a between-subjects factor. This analysis revealed a significant interaction between Condition and Label Type, $F(4, 148) = 3.99$, $p = .004$, $\eta_p^2 = 0.097$. Figure 5 shows that similar to name labels, occupation labels yielded better performance than nonlabeled faces, whereas person-unrelated labels did not improve recognition relative to nonlabeled faces. To assess the effect of the different label types relative to the gender-consistent name label, we ran mixed ANOVA with Condition (labeled, nonlabeled) as a within-subject factor and Label Type (symbol, object name, female name, occupation, male name) as a between-subjects factor. The improved recognition for faces associated with male name labels relative to the nonlabeled faces was significantly larger than that of faces associated with symbol labels, $F(1, 61) = 15.95$, $p < .001$, $\eta_p^2 = 0.21$, object name labels, $F(1, 61) = 6.9$, $p = .011$, $\eta_p^2 = 0.1$, and female name labels, $F(1, 61) = 4.51$, $p = .038$, $\eta_p^2 = 0.069$. However, occupation labels did not significantly differ from male name labels, $F(1, 61) = 1.05$, $p = .31$, $\eta_p^2 = 0.017$, and similarly showed better recognition for labeled than nonlabeled faces, $F(1, 61) = 14.69$, $p < .001$, $\eta_p^2 = 0.19$. Overall, these findings suggest that person-related labels enhanced face recognition, whereas labels that are not typically associated with faces do not enhance face recognition.

We also examined whether the exposure to different label types had different effects on the two types of face images we presented in the test session (see Table 4 of the online supplemental materials). A mixed ANOVA with Condition (labeled, nonlabeled) and Face Type (different lighting, different view and lighting) as a within-subject factor, and Label Type (symbol, object name, female name, occupation, male name) as a between-subjects factor, revealed a main effect for Face Type, $F(1, 148) = 58.03$, $p < .001$, $\eta_p^2 = 0.28$, indicating overall improved recognition for faces that differ in lighting than faces that differ in both view and lighting, and an interaction between Face Type, Label Type, and Condition, $F(4, 148) = 4.33$, $p = .002$, $\eta_p^2 = 0.11$. Separate analyses for the

Table 4
Mean (Standard Deviation) of d' and Proportion Correct for the Labeled and Nonlabeled Faces in Experiment 4

Performance measures	Symbol task		Object name task		Female name task		Occupation task		Name task	
	Symbol	No label	Object name	No label	Female name	No label	Occupation	No label	Name	No label
d'	1.76 (.83)	1.96 (.8)	2.13 (.83)	2.15 (.77)	2.03 (.77)	1.99 (.96)	2.35 (.63)	2.16 (.77)	2.3 (.75)	1.97 (.7)
Proportion correct	.78 (.15)	.8 (.14)	.83 (.13)	.83 (.11)	.81 (.12)	.8 (.14)	.85 (.11)	.82 (.13)	.85 (.11)	.8 (.15)

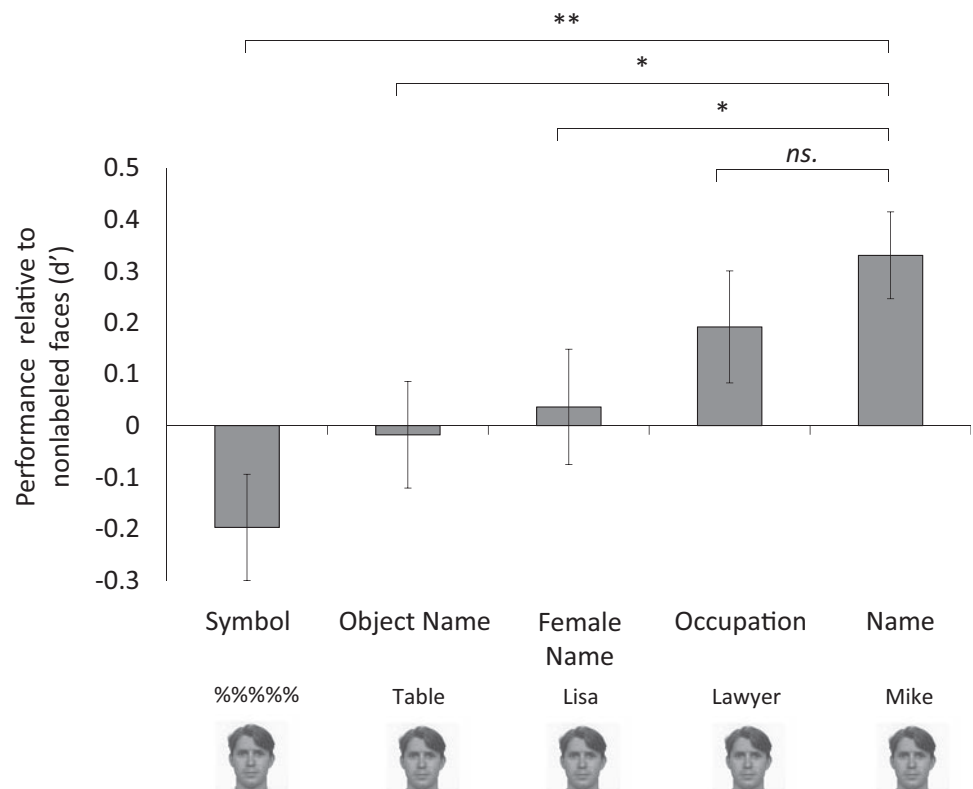


Figure 5. The difference between performance (d') for labeled and nonlabeled faces as a function of label type (see also Table 4). Person-related labels such as name and occupation enhance face recognition relative to nonlabeled faces, whereas person-unrelated labels do not. Error bars indicate the standard error of the difference between the label and the nonlabeled control faces of each of the label types. * $p < .05$. ** $p < .005$.

two different test face images were conducted for each of the labels. Analysis showed that the effect of the male name label was marginally larger for the different view and lighting than different lighting faces, $t(32) = 1.77, p = .09$, Cohen's $d = 1.05$, whereas the effects of Symbol, $t(29) = 0.29, p = .77$, Cohen's $d = 0.05$, Object Name, $t(29) = 1.56, p = .13$, Cohen's $d = 0.28$, Female Name, $t(29) = 1.11, p = .27$, Cohen's $d = 0.2$, and Occupation, $t(29) = 0.41, p = .68$, Cohen's $d = 0.07$, did not differ between the different lighting and different-view-and-lighting test faces compared with their nonlabeled control faces.

Label Retrieval Phase

For the analysis of the label retrieval rate, 131 of the 133 participants were included in the analysis—data for two partici-

pants (one from the symbol task and one from the object task) were not collected because of technical problems. We compared the performance of all label tasks used in Experiment 4. For the male name condition, we included the results that were collected in Experiment 2 as well as the results of the additional 13 subjects that were added in Experiment 4. Table 5 shows the proportion of labels that were or were not retrieved for recognized and unrecognized faces. To assess whether some labels were easier to recall than others, we computed the proportion of correct label recollection.

We ran a one-way ANOVA over the five different label conditions (symbol, object name, female name, occupation, male name) on the proportion of label retrieval for faces that were recognized during the recognition phase. A marginally significant effect for

Table 5
Percentage of Label Retrieval for Recognized and Unrecognized Faces

Label type	Recognized faces with correct label retrieval	Recognized faces with no label retrieval	Unrecognized faces with correct label retrieval	Unrecognized faces with no label retrieval
Symbol	47% (2.56)	27% (2.0)	8% (1)	19% (1.36)
Object name	53% (2.2)	28% (1.85)	8% (.86)	11% (1.29)
Female name	45% (2.07)	33% (1.66)	7% (.69)	16% (1.21)
Occupation	62% (2.04)	20% (1.66)	12% (.97)	7% (.83)
Name	55% (2.41)	30% (1.95)	7% (.67)	9% (.94)

label was found, $F(4, 146) = 3.62$, $p = .08$, $\eta_p^2 = .09$. Post hoc comparisons showed better retrieval of occupation labels than symbol labels ($p = .034$) and female name labels ($p = .006$). No differences were found between retrieval of male name labels than any of the person-unrelated labels. These findings suggest that the enhancement in face recognition for faces associated with name labels is not because of the labels themselves being better remembered than person-unrelated labels.

Discussion

Experiment 4 replicated and extended the findings we reported in the previous experiments. Associating faces with object names or symbol labels did not enhance face recognition relative to nonlabeled faces. However, other person-related labels, such as occupations, did enhance face recognition in the same way that faces associated with gender-consistent names did. These findings suggest that names are not special and that associating faces with other congruent person-related conceptual information during familiarization also contributes to face recognition.

Our findings that labels that are not typically associated with faces do not enhance face recognition may seem inconsistent with studies that showed that arbitrary labels enhance recognition of novel objects. For example, Lupyan et al. (2007) found an advantage for learning labeled novel objects over nonlabeled novel objects, even when the labels were nonsense words (“leebish” or “gracious”) that did not convey any information that was relevant to the categorization or the task. Another study found that association of arbitrary adjectives to novel objects (“sleepy and angry,” “fast and lazy”) can alter the visual representation of the objects and influence discrimination rates (Gauthier et al., 2003). However, there are two important differences between these studies and our study. First, novel objects are meaningless stimuli that are not associated a priori with any conceptual information and, therefore, may be more readily associated with any arbitrary label. Faces, on the other hand, even if unfamiliar, are a familiar category that is already associated with certain conceptual information. Second, previous studies used much longer duration of training, in which the novel objects and the labels were repeatedly presented over several blocks, whereas in our study, each face was presented with its associated label only 10 times in one block. It is possible that additional repetitions would reveal an effect for unrelated labels as well. Importantly, however, our design allowed us to reveal that even such relatively short exposure of a face with person-related labels is enough to enhance recognition. We will further discuss this finding in the General Discussion.

In this experiment, we also examined performance of label recollection following face recognition. During this phase, subjects were presented with the faces they learned during the familiarization phase and were asked to indicate which of the faces were associated with labels, and to retrieve the labels that were associated with the labeled faces. Our findings indicate that name labels were not better recalled than labels that did not improve face recognition, such as symbols, object names, or female names, whereas occupation labels were better recalled than person unrelated labels (see Table 5). These results are consistent with findings that shown that name retrieval is relatively poor for familiar/familiarized faces relative to other semantic information such as occupation or nationality (Hay et

al., 1991; R. A. Johnston & Bruce, 1990; Yarmey, 1973; Young et al., 1986, 1988). To address these findings, Bruce and Young’s (1986) model suggested that faces and their person identity nodes (PINs), in which conceptual information such as occupations is being stored, are connected using a single link. An additional link connects the PIN and the relevant name of the face (see also Hanley, 2011, for review). Based on this model, conceptual information such as occupation should be easier to retrieve than name, as learning an occupation involves creating a direct link between the face recognition unit and the PIN, whereas learning a name requires creating two links. Our study indeed found that names were harder to recall than occupations, but that the mere recognition of faces was not affected by succeeding to retrieve the learned labels. Therefore, although occupations were easier to retrieve, faces associated with occupation labels were not better recognized than faces associated with name labels. Furthermore, although named faces were better recognized than faces associated with symbols or object names, people names were not better recalled than person-unrelated labels that did not enhance face recognition. These findings suggest that the enhanced recognition for person-related labeled faces does not derive from better memory of the labels themselves, but instead suggest that the improved recognition is mediated by processes that take place during the encoding phase, when the association between the face and the person-related label is made.

To conclude, findings of Experiment 4 show that unfamiliar faces that are presented with person-related labels such as a person name or occupation are better recognized from new images of the same identity than nonlabeled faces. This effect was not found for faces that were associated with person-unrelated labels such as symbols or object names. Furthermore, person-related labels (in particular people names) were not better retrieved than person-unrelated labels when subjects were presented with the faces without labels and were asked to retrieve their label. This finding suggests that faces associated with person-related labels are better recognized not because their labels are better remembered. Instead, the association of a person-related label, but not of a person-unrelated label, with a face during encoding may generate a view-invariant conceptual representation, as will be further discussed in the General Discussion.

General Discussion

The goal of this study was to assess the roles of perceptual and conceptual information in face recognition. These two factors typically go together when faces become familiar in real life, as we are both exposed to many different images of the familiarized person but also accumulate conceptual information associated with them, such as their name, occupation, where they live, and so on. Thus, we cannot examine the sole contribution of each of these factors by studying familiar faces, but instead can study the learning process by which an unfamiliar face becomes familiar. To dissociate between these two factors, we designed a face familiarization task in which we either presented faces across different views and lighting (multiview/perceptual condition) or presented them from a single view but with a unique person-related label (name/conceptual condition; see Figure 1). This allowed us to

directly compare between the effects of these two factors that were examined thus far in separate studies. Our findings show that exposure to rich perceptual information during which a face is presented across different views and lighting did not improve face recognition relative to presentation of a face from a single view. In contrast, single-view faces that were associated with unique person-related labels, such as names or occupations, were better recognized than nonlabeled faces. This effect was not found when faces were associated with labels that were not related to people, such as symbols (e.g., #####, %%%%) or object names. An important feature of our study was that face recognition was examined for new images of the learned faces, and therefore required generalization across different images of the same person rather than image-based face matching. This is critical if our main goal was to account for the recognition of familiar faces, as this is the main feature that differentiates between the error-prone matching of different images of the same identity of unfamiliar faces and the robust view-invariant representation that we have for familiar faces (Jenkins & Burton, 2011).

The findings that presentation of multiple-view images of the same face did not improve recognition relative to single-view exposure may seem surprising at first. Notably, we do not suggest that rich perceptual information by itself cannot contribute to face recognition under any circumstances, but only conclude that the amount of exposure that we provided did not enhance face recognition, whereas a similar exposure to faces with names did improve the recognition of named faces. Using a wider and more variable sample of photos of each individual (e.g., Murphy et al., 2015) or a different perceptual learning task (Andrews et al., 2015) may improve face recognition. It is noteworthy, however, that another support for the absence of effect for pure perceptual information on face recognition was reported in a recent study that examined newborn face recognition in neonatology nurses who, despite massive perceptual exposure to newborn faces in their workplace, did not recognize newborn faces better than controls who had minimal exposure to newborn faces (Yovel et al., 2012). These results suggest that real-life perceptual exposure that was not accompanied by association of conceptual information with individual faces does not contribute to face recognition. Indeed, a short individuation training (based on Tanaka et al., 2005) with naïve participants who had no prior experience with newborn faces, during which newborn faces were associated with unique names, enhanced recognition of the trained newborn faces and was also generalized to novel newborn faces. These findings again show that massive but passive exposure to faces does not improve face recognition whereas relatively short training during which a face is associated with a name does improve recognition. The current study provided a more systematic comparison between the roles of perceptual and conceptual information in face processing and reveals the important role of conceptual information in the process of face familiarization.

Previous studies that have shown that name labels improved recognition of the labeled faces (McGugin et al., 2011; Tanaka & Pierce, 2009) attributed this effect to processes of subordinate individuation, which better highlight finer differences between faces associated with different labels (Levin, 2000; Tanaka & Pierce, 2009). However, our findings show that the process of individuation alone may not account for the improved recognition that we found for person-related labels, as it predicts that any label

associated with a percept would enhance recognition relative to nonlabeled or similarly labeled faces. We therefore consider another mechanism that may enable the generation of a view-invariant representation, according to which faces that are associated with person-related labels undergo a representational shift from an image-based percept to a view-invariant concept. A similar idea was suggested by Lupyan (2008), who examined the effect of object name labels on object recognition. A basic-level label of a “chair,” for example, which was presented with a picture of a chair, impaired recognition of the specific image presented during the learning stage by shifting its representation from the image-based exemplar level of a specific chair to the more prototypical representation of the category *chair*. One difference between Lupyan’s and our study is that the label he used is a familiar label (“chair”) that is already associated with the learned image (a chair). In our study, we presented labels (e.g., person name) that are not informative with respect to the visual image of the face (e.g., the name “David” does not indicate what the face would look like), but because they are conceptually associated with the category (the name of a person is typically associated with a face), they influenced the nature of the representation of the learned face. Still, in cases in which labels may provide semantic information about faces, they may further influence its representation. For example, we also found that associating gender-inconsistent names had a smaller effect than gender-consistent names. These findings suggest that relevant semantic information may enhance face recognition more than inconsistent semantic information. Future studies may further examine whether conceptual labels that are informative with respect to the visual representation of a face may further enhance recognition abilities. For example, it has been shown that certain facial features are more likely to be judged as trustworthy or dominant (Oosterhof & Todorov, 2008; Todorov, 2008). In our study, labels were randomly associated with the different faces. The question is whether systematically associating congruent versus incongruent traits to faces during a familiarization task may influence face recognition.

The role of conceptual knowledge in object recognition has been demonstrated in additional studies. For example, conceptual knowledge was also suggested to account for the better visual search that is reported for familiar than unfamiliar stimuli. In particular, Lupyan and Spivey (2008) presented 90° rotations of the Numbers 2 and 5 in a digital font in a search array. Performance was significantly better when subjects were told that these are rotated numbers than when they treated them as novel meaningless stimuli. They concluded that perception is enhanced for meaningful versus nonmeaningful stimuli by top-down mechanisms generated by conceptual labels, which modify the visual representation of the image (see also Lupyan, Thompson-Schill, & Swingle, 2010). Other studies that examined the role of perceptual and conceptual information in long-term memory of objects and scenes have shown that conceptual distinctiveness rather than perceptual information better predicted recognition of the learned images (Konkle et al., 2010a; Konkle, Brady, Alvarez, & Oliva, 2010b).

One difference between the role of conceptual information in familiar objects and faces that should be noted is that object labels typically represent a category or a subcategory, whereas face labels are typically associated with specific individuals. This may play an important role in discrimination and generalization processes at the

required level of categorization. For faces, conceptual information allows us to discriminate among many different familiar faces and generalize across the different images of the same person, whereas for objects, conceptual information allows discrimination among subcategories but does not support discrimination among exemplars of a given subcategory. Recognition at the exemplar level for objects is mainly performed by experts who may also benefit from the rich conceptual information they associated with different exemplars.

The idea that conceptual rather than perceptual information enhance the visual representation of a face may be also consistent with previous studies that asked subjects to learn faces while making either perceptual judgments (e.g., are the eyes of the face large?) or conceptual judgments, such as trait inferences, about faces (e.g., how intelligent does the face look like?). These studies reveal much better recognition for faces following trait than perceptual judgments (Bower & Karlin, 1974; Courtois & Mueller, 1979; Winograd, 1976, 1978, 1981). Two possible explanations have been suggested to account for this effect. The semantic quality hypothesis suggests that conceptual judgments lead to deeper encoding of faces, by creating a rich, semantic network of associations for a given face (Bower & Karlin, 1974). Alternatively, the feature quantity account suggests that conceptual judgments lead to more elaborative scanning of the face and, consequently, encoding of more facial features (see also Winograd, 1978, 1981). Consistent with the semantic quality hypothesis, we suggest that a shift in the representation from a percept to a concept occurs when we make trait inferences about faces, but not when we make perceptual judgments about faces, in which case the representation remains at the perceptual-image-based level. It is noteworthy that previous studies that compared recognition of faces following perceptual and conceptual judgments presented the same face image in both study and test, and therefore did not examine whether trait inferences generated a view-invariant representation of a face. We predict that conceptual judgments would generate a more invariant representation of the face than perceptual judgments.

Overall, we suggest that association of conceptual information with faces (or objects) changes the representation from an image-based perceptual representation that is likely to be primarily processed by occipitotemporal visual areas to a conceptual representation that is represented in more anterior temporal areas and is more view-invariant in its nature. In fact, the *concept neurons* that were revealed in the medial temporal lobe for familiar faces and scenes (Quiroga, Reddy, Kreiman, Koch, & Fried, 2005; for review, see Quiroga, 2012) may be the neural manifestation of such view-invariant conceptual representation. These neurons are similarity activated by various views of the same person as well as the person name. These neurons also respond to masked faces of familiar individuals (e.g., the masked faces of Halle Berry as she appeared in one of her movies), and in this way show that person knowledge may expand the invariant representation of an identity of a person beyond the information that can be obtained from perceptual information alone. We suggest that the unique conceptual information that we have about each of the familiar faces we know may play an important role in linking together the many different exemplars of the same person we encode each time we encounter them. Thus, during the process by which an unfamiliar face becomes familiar, perceptual and conceptual information are

integrated to generate the robust view-invariant representation and allow the superior recognition abilities that we have for familiar faces.

A set of Event-related potential (ERP) studies conducted by Paller and colleagues examined the neural correlations of faces following association with semantic information, and focused on the recollection and retrieval of these learned faces (Paller, Gonsalves, Grabowecky, Bozic, & Yamada, 2000; Paller et al., 2003). These studies found that faces that underwent association with semantic information elicited larger amplitudes in the anterior midline area during the test phase (Paller et al., 2000, 2003). This pattern of activations has been suggested to derive from the retrieval of biographical information of the faces associated with semantic information (both verbal and nonverbal). Paller and colleagues (2003) further suggested that the semantic information that was associated with the learned faces was stored in a network of frontal and temporal locations, and thus retrieving the information results in larger activations (Ranganath & Paller, 1999; Ranganath, Johnson, & D'Esposito, 2000, 2003). Whereas these studies focused on the representation of the semantic information that is associated with a face, rather than the representational of the face itself, ERP studies by Gordon and Tanaka (2011) have shown that faces associated with names generated larger N250 and that this effect got larger with repeated presentations of the faces but not for faces that were not associated with names. The enhanced N250 may reflect a shift in the representation of a face from a pure perceptual image to a conceptual representation. The N250 has been shown to be more sensitive to familiar than unfamiliar faces (Kaufmann, Schweinberger, & Burton, 2009; Schweinberger, Pickering, Jentsch, Burton, & Kaufmann, 2002), and may be therefore affected by conceptual information rather than purely perceptual aspects of the familiar/familiarized face.

The enhancing effect of names may be surprising, given findings showing that retrieval of names is a challenging task, and more so relative to retrieval of other semantic information such as occupation (R. A. Johnston & Bruce, 1990; Young et al., 1986, 1988). Interestingly, in our study, we found that label retrieval was not associated with the ability to recognize the face associated with the label. That is, retrieval of people names was no better than retrieval of symbols, object names, or female names that were associated with faces, despite the fact that names enhanced face recognition, whereas the other labels did not. These findings suggest that despite the fact that name retrieval is challenging, name labels still play an important role in face recognition when they are associated with faces during encoding.

Whereas the main motivation of our study was to account for the superior recognition that we have for familiar faces, our study examined only short-term learning, which does not reflect the way familiar faces are typically recognized in real life. It will therefore be interesting to assess whether the effect that we revealed by associating person-related labels to faces also remains for long-term delays between study and the test. By showing that person-related labels allow recognition of different images of the same face, we at least show that recognition is not based on short-term image-based processes, but that person related labels generated a more abstract representation that can be generalized to new images. This type of view-invariant representation is exactly what differentiates between the pictorial image-based code that we have for unfamiliar faces and the structural view-invariant representa-

tion that we have for familiar faces (Bruce & Young, 1986; Jenkins & Burton, 2011). It will be interesting to assess in future studies whether this abstract representation remains following long-term delays between familiarization and recognition stages.

Our study is consistent with theories that encourage the integration of perception and cognition in the understanding of face and object recognition (e.g., for review, see Goldstone & Barsalou, 1998; Konkle et al., 2010a; Lupyan et al., 2010; Palmeri, & Gauthier, 2004; see also Burton et al., 1999, for a model that integrates perception and cognition for face recognition). Face recognition has been often studied in the context of perception by assessing the roles of parts, wholes, and configuration (e.g., for review, see Maurer, Grand, & Mondloch, 2002), as well as different image-based manipulations such as negation (Russell, Sinha, Biederman, & Nederhouser, 2006) and inversion (e.g., for review McKone & Yovel, 2009). The role of nonperceptual information has been assessed in individuation training studies discussed above or in recognition studies of familiar or familiarized faces that typically assessed recollection of the semantic information associated with faces (Paller et al., 2000; Todorov, Gobbini, Evans, & Haxby, 2007; Yovel & Paller, 2004), rather than its effect on the recognition of the faces themselves. Here, we highlight that in order to understand face recognition, both the perceptual and the conceptual information associated with faces should be considered.

Taken together, this series of experiments revealed a set of novel findings that highlight the important role of conceptual information in face recognition. First, we found that for the same amount of exposure, associating faces with names improved face recognition of new images of the learned faces, whereas presenting faces across different views and lighting did not. Furthermore, the advantage we revealed for named faces cannot be generalized to any type of labels, but relies greatly on providing person-related information about a face. These findings suggest that the role of conceptual information should be considered in the process of face recognition and, in particular, in our attempt to understand the superior recognition that we have for familiar faces.

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