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Perceptual Integrality of Sex and Identity of Faces: Further Evidence for the Single-Route Hypothesis

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According to current face-recognition models, sex (gender) and identity of faces are processed in independent routes. Using Garner's speeded-classification task, the authors provide evidence that sex and identity are processed within a single route. In 4 experiments, participants judged the sex or the familiarity of faces while the other dimension remained constant or varied randomly. The results of Experiments 1, 2, and 4 showed that participants could not selectively attend to either sex or familiarity without being influenced by the other, irrelevant dimension. Thus, identity and sex are integral dimensions. Experiment 3 provided evidence that when sex judgments are based on hairstyle heuristics, false separability can emerge. The findings support the claim that identity and sex are processed within a single route.

This article is concerned with the cognitive architecture of the face-recognition system. We focus on the relationship between two classes of face-related processes. The first class, *face identification,* involves the recognition of a particular face and is based on information regarding the identity of individual faces. Face-identification processes include deciding whether a particular face is familiar, to whom a particular face belongs, or in what prior context a particular face was seen.

The second class of processes, *face classification,* is not specific to recognizing a particular individual, but is based on visual information that is "similar to all 'facial action patterns' irrespective of the faces that are making them" (Bruce, 1988, p. 32). Face-classification processes include the extraction of attributes such as sex, expression, race, age, and mouth shape. The current study explored the relationship between face-identification and face-classification processes.

Earlier studies have used several tasks to examine the two classes of processes. Face-identification tasks include retrieval of the names of familiar faces (*What is the name of the celebrity in the picture?*; e.g., Ellis, Flude, Young, & Burton, 1996), face recognition (*Did you ever see this face before?*; e.g., Munte et al., 1997), face-occupation judgments (*What is the profession of the celebrity whose picture is presented?*; e.g., Hanley, Smith, & Hadfield, 1998), and face-familiarity judgments (*Is this person familiar or not?*; e.g., Ellis, Young, & Flude, 1990). Face-classification tasks include expression judgments (*Is this face happy or sad?*; e.g., Ellis et al., 1990; Schweinberger, Burton, & Kelly, 1999; Schweinberger & Soukup, 1998), lipreading judgments (*Is this face saying "oo" or "ee"?*; e.g., Campbell, Brooks, De Haan, & Roberts, 1996), race classification (Levin, 1996; Valentine & Endo, 1992), and sex judgments (*Is this a man or a woman?*; e.g., Bruce, 1986; Goshen-Gottstein & Ganel, 2000; Hay, 1999). In the current experiments, we studied the relationship between the face-identification task of familiarity judgments and the face-classification task of sex judgments.

According to face-recognition models (e.g., Bruce & Young, 1986; Burton, Bruce, & Johnston, 1990; Hay & Young, 1982), information regarding face identification is represented by abstract, structural records (e.g., Kirsner & Dunn, 1985). The structural records are abstract in the sense that they can be reactivated with subsequent visual encounter of a face or, within other domains of visual processing, by any other item, such as a word (e.g., Jacoby & Dallas, 1981), a nonword (e.g., Bowers, 1994; Dorfman, 1994), a word-pair (e.g., Goshen-Gottstein & Moscovitch, 1995a, 1995b; Goshen-Gottstein, Moscovitch, & Melo, 2000), or a line drawing (e.g., Schacter, Cooper, & Delaney, 1990), regardless of the specific visual aspects of the viewing scene (e.g., the size, angle, or lighting). In the case of faces, the abstract records are thought to be stored in *face-recognition units* (FRUs), or face modules (Moscovitch & Umiltà, 1990, 1991; Moscovitch, Winocur, & Behrmann, 1997; for recent reviews, see Kanwisher & Moscovitch, 2000) and enable the identification of known faces.

Orthodox models of face recognition propose that when face-classification information is accessed, processing occurs in routes that run parallel to the FRUs (Bruce & Young, 1986; Burton et al., 1990).[1] According to this *parallel-route hypothesis,* face-classification processes, which do not involve any information

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[1] Although almost all face-recognition models postulate the existence of some form of abstract structural records (whether they are called FRUs or face modules), there are also different views. For an exemplar-based model of face-relevant processes, which does not postulate the existence of FRUs, see Hay (1999).

regarding the identity of faces, are made through a parallel pathway that is not mediated by the FRUs and depends on facial aspects that are different from the ones that are used for face-identification processes.

A review of the literature suggests that the parallel-route hypothesis provides a good account of the relationship between the processing of expression and face identification as well as of the relationship between lipreading and face identification. Several lines of evidence converge on this conclusion. First, the pattern of performance found in normal healthy participants supports the notion that expression and lipreading judgments are not mediated by FRUs (Bruce, 1986; Etcoff, 1984; Young, McWeeny, Hay, & Ellis, 1986). Second, a neuropsychological double dissociation has been observed between face identification and expression judgments and also between face identification and lipreading judgments (Campbell, Landis, & Regard, 1986; Humphreys, Donnelly, & Riddoch, 1993; Schweich & Bruyer, 1993; Tranel, Damasio, & Damasio, 1988; Young, Newcombe, de Haan, Small, & Hay, 1993). Third, human brain imaging studies have found a different pattern of activation during identity judgments than during expression judgments (for a comprehensive review, see Haxby, Hoffman, & Gobbini, 2000) and lipreading judgments (Calvert et al., 1997). Finally, studies of single-cell recordings in monkeys found that different cells respond to the identity than to the expression of faces (for a review, see Gauthier & Logothetis, 2000; however, see Sugase, Yamane, Ueno, & Kawano, 1999).

In contrast to the support for the parallel-route hypothesis regarding the relationship between expression (and lipreading) and identity, recent findings are accumulating to suggest that sex and identity are processed by a single route (henceforth, the *single-route hypothesis*). First, only a single dissociation has been reported between the processing of identity and sex, with patients showing impaired recognition of the identity of faces but a preserved ability to make correct sex judgments (e.g., Tranel et al., 1988). Because the reverse dissociation has not been documented, it is possible that relative task difficulty accounts for this dissociation rather than a qualitative difference in processing.

Second, behavioral data from healthy individuals also fail to support the parallel-route hypothesis. Such data have, to date, been based on the repetition-priming effect, defined as a facilitation in performance to studied, as compared with unstudied, items (e.g., Richardson-Klavehn & Bjork, 1988). For example, in the speeded-familiarity task, participants are presented during study with a series of familiar faces (e.g., a photo of George W. Bush). Then, during test, they are presented with a second series that includes studied and unstudied familiar faces as well as unfamiliar faces. Participants typically decide that a face is familiar more accurately and quickly if that face was previously shown in the first series than if it was not (e.g., Ellis et al., 1996; Henson, Shallice, & Dolan, 2000).

Repetition-priming effects have been argued to result from the reactivation of structural facial information that is stored in the FRUs. Presumably, with repeated presentation of a face, the information stored in the FRUs is reactivated, thereby leading to facilitated processing of this face.

According to the parallel-route hypothesis (e.g., Bruce & Young, 1986), only face-identification tasks (e.g., familiarity judgments), which depend on structural information that is stored in FRUs, can benefit from earlier activation. However, face-classification tasks, which require information that is similar to all facial patterns irrespective of their identity, are not mediated by FRUs and are predicted, therefore, to not benefit from earlier activation and, consequently, to show no repetition priming. This prediction was confirmed in a frequently cited study by Ellis et al. (1990), who failed to find repetition priming for sex judgments, suggesting that sex judgments do not involve FRUs.

Recently, however, Goshen-Gottstein and Ganel (2000) suggested that the failure to observe repetition priming in the sex-judgment task was because participants in Ellis et al.'s (1990) study judged the sex of the photos by applying hairstyle heuristics that bypassed the FRUs. Such hairstyle heuristics are superficial perceptual processes that direct participants' attention away from the crucial, internal facial features, so that sex judgments are based entirely on hairstyle (e.g., long hairstyle for female faces and short hairstyle for male faces). Goshen-Gottstein and Ganel suggested that because the internal facial features were not processed in Ellis et al.'s study, FRUs were not reactivated, and repetition effects could not emerge.

In support of this suggestion, Goshen-Gottstein and Ganel (2000) found that when edited, hair-deleted faces were presented for sex judgments, repetition effects did emerge. Presumably, once hairstyle heuristics were prevented, participants could base their sex judgments on only the internal facial features, thereby activating the FRUs and enabling repetition effects to emerge. Furthermore, when complete, hair-included faces were presented for sex judgments, Ellis et al.'s (1990) failure to obtain repetition priming was replicated, implicating the role of hairstyle heuristics in mediating sex judgments for hair-included faces. These results provide support for a single rather than a parallel route for the processing of sex and identity of faces (for a similar conclusion, see Baudouin & Tiberghien, 2002; Calder, Burton, Miller, Young, & Akamatsu, 2001; Hay, 1999; Rossion, in press).

Brain imaging studies have also addressed the question of single versus parallel routes for the processing of sex and identity. An initial report by Sergent, Otha, and Macdonald (1992) actually found some differences in brain activation between sex and identity judgments. Interpretation of these results is problematic, however, because the two tasks were confounded with the familiarity of faces (familiar or unfamiliar). Activation of different brain regions during the two tasks was probably, therefore, a function of differences in the familiarity of faces (for a similar conclusion, see Dubois et al., 1999).

Most important, a positron emission tomography (PET) study, in which the confound between task and familiarity was removed, supported the single-route hypothesis. Dubois et al. (1999) explored the neural substrates that correspond to sex and identity judgments. Identical brain activity was found for both judgments, primarily in the fusiform face area (FFA), which is known as a cerebral region that is engaged in face processing and identification (Gauthier et al., 2000; Kanwisher, Stanley, & Harris, 1999).

In addition, Dubois et al. (1999) examined the effects of familiarity of faces (unfamiliar or familiar) on the pattern of brain activity during sex judgments. The pattern of activation found for familiar, as compared with unfamiliar, faces can be directly compared with the repetition effects (advantage to studied as compared with unstudied faces) reported by Goshen-Gottstein and Ganel (2000), in that the set of familiar faces that were used in Dubois et al.'s study were actually unfamiliar faces that had been familiar-

ized during the experimental sessions (i.e., studied faces). It is likely, therefore, that the difference in the pattern of brain activation to these studied faces as compared with the unstudied faces was a signature of the repetition-priming effect.

Dubois et al. (1999) found that sex judgments for studied faces, as compared with unstudied faces, produced a decrease of activity in early visual brain areas (V1, V2, and V3). This decrease is known to reflect repetition priming for visual information (Squire, Knowlton, & Musen, 1993; Ungerleider, 1995). Therefore, this finding provides converging neuroanatomical evidence that sex judgments can produce repetition effects (Goshen-Gottstein & Ganel, 2000).

Recently, the demonstration of neuroanatomical repetition effects for sex judgments was replicated. Similar to Dubois et al. (1999), Rossion, Schiltz, Robaye, Pirenne, and Crommelinck (2001) also found that sex judgments for studied faces, as compared with unstudied faces, produced a decrease in brain activity, thereby providing a second neuroanatomical replication of the behavioral findings of Goshen-Gottstein and Ganel (2000). Together, the convergence of behavioral and neuroanatomical data supports the notion that a common pathway is involved in processing of the sex and of the identity of faces.

Dubois et al. (1999) used PET imaging to argue for common FFA activity for identity and sex judgments. Unfortunately, the idea that sex and identity are processed together at every stage of information processing requires further evidence, because the temporal resolution of PET imaging is very low (Raichle, 1994). Indeed, the studies of Goshen-Gottstein and Ganel (2000), Dubois et al. (1999), and Rossion et al. (2001) provided only limited support for the single-route hypothesis, in that these studies investigated the relationship between identity and sex judgments as uncovered at (relatively late) processing stages in which memory (i.e., repetition effects) was involved. Thus, a milder version of the parallel-route hypothesis might be true in which, for example, sex and identity are initially processed separately but converge at a later cognitive stage, to elicit an identical pattern of brain activity when confronted with mnemonic tasks.

To support the idea of a single neuroanatomical pathway not only at a late stage of processing but even at early stages of initial perception, evidence from a perceptual paradigm is needed. In this article, such evidence is provided using Garner's speeded-classification task (see Garner, 1974).

Garner's Speeded-Classification Task

Garner's speeded-classification task provides a rigorous test of perceptual separability between stimulus dimensions (Maddox, 1992). Garner's analytical approach to selective attention fully recognizes that the objects in people's perceptual milieu are multidimensional. In a similar manner, faces are complex, multidimensional stimuli, consisting of dimensions such as race, age, sex, and identity. Garner's paradigm explores the important question of whether humans can attend to one dimension of a multidimensional object while ignoring other dimensions.

In this article, we asked whether attention can be successfully directed to people's sex while identity is ignored. In one block of the Garner task (the baseline block), the irrelevant dimension (e.g., sex) is held constant, and only the relevant dimension (identity) varies from trial to trial. In the other block (the filtering block), both dimensions vary from trial to trial in a random fashion. If performance at classifying identity is equal in the baseline and filtering blocks, then selectivity is perfect, and the dimensions are labeled *separable*. If, on the other hand, performance in filtering is worse than that at baseline—Garner interference—then selectivity has failed, and the pair of dimensions is labeled *integral*. We now elaborate on our prediction regarding the integrality of the dimensions of sex and identity. Subsequently, we explain in detail how Garner's paradigm can be applied to test the relationship between these dimensions.

Considerable research has explored the relationship between many types of dimensions of diverse classes of objects. Examples of integral dimensions are the dimensions of color and brightness (Garner & Felfoldy, 1970; Hyman & Well, 1968), the width and the height of a rectangle (Felfoldy, 1974), the orientation and length of lines (Dick & Hochstein, 1988), and the color and meaning of color words (Melara & Mounts, 1993; cf. Algom, Dekel, & Pansky, 1996; Shalev & Algom, 2000).

Examples of separable dimensions are the dimensions of color and shape (Gottwald & Garner, 1972), size and brightness (Attneave, 1950), and the contrast and position of lines (Shechter & Hochstein, 1992). Garner's paradigm typically examines selective attention to different attributes of the same object's dimensions; hence, virtually by definition, the dimensions inhere in the same spatial location. It is, therefore, eminently possible that dimensions that belong to the same form (as sex and identity in our study that belong to the same face) can be separable. This is exactly the case with, for example, the dimensions of circle size and inscribed diameter orientation (Felfoldy & Garner, 1971) and of contrast and size of lines (Shechter & Hochstein, 1992), which are separable dimensions. Another relevant example of separability between dimensions that belong to the same form is between the physical and numerical size of numerals (Algom, Dekel, & Pansky, 1993, 1996; Pansky & Algom, 1999, 2002). The last example is of particular relevance to the current study because it shows that perceptual (i.e., physical size) and conceptual (i.e., numerical size) aspects of the same form can be separable dimensions. In the current study, we asked whether perceptual (i.e., sex) and conceptual (i.e., familiarity) dimensions that belong to the same form (i.e., the face) are indeed separable dimensions.

Garner's task has also been applied to face-relevant dimensions (Ben-Artzi & Gilboa-Schectman, 2001; Etcoff, 1984; Schweinberger et al., 1999; Schweinberger & Soukup, 1998). Schweinberger et al.'s (1999) and Schweinberger and Soukup's (1998) studies used Garner's task to the test the relationship between the face-relevant dimensions of identity and expression and between identity and facial speech (i.e., mouth shape). The results of these studies generally supported the predictions of the parallel-route hypothesis for the dimension of expression and identity and the dimensions of facial speech and identity; judgments of identity in these studies were unaffected by irrelevant variations in expression (or facial speech), and these dimensions were, therefore, separable (but see the General Discussion).

The perception of the dimensions of expression (and facial speech) and identity as separable Garner dimensions is in harmony with the neuropsychological data showing a double disassociation between the processing of identity and expression (e.g., Humphreys et al., 1993) and also converges with brain imaging studies showing that these processes are performed in distinct brain areas

(e.g., Breiter et al., 1996). The functional separability of the dimensions of identity and expression seems, therefore, to reflect a corresponding neuroanatomical separability. Will the dimensions of identity and sex, which seem to be processed via a single neuroanatomical route, also show correspondence to neuroanatomical data and be found to be integral?

Garner's paradigm was applied in this study to the dimensions of identity and sex of faces. Because the studies that are most directly relevant to ours used familiarity decisions to represent identity judgments (Bruce, 1986; Dubois et al., 1999; Ellis et al., 1990), we also operationalized identity by degree of familiarity to avoid possible criticisms of task differences across studies.[2]

In the current study, we used a stimulus set that consisted of four stimuli made by a factorial combination of two dimensions: identity (familiar or unfamiliar) and sex (male or female), thereby producing four possible combinations: familiar male, familiar female, unfamiliar male, and unfamiliar female. On each experimental trial, participants were asked to make speeded classifications of a relevant stimulus dimension while ignoring the other irrelevant dimension. Experimental trials were divided into two experimental blocks: baseline and filtering.[3]

In the baseline blocks, participants made speeded classifications of the relevant dimension (e.g., familiarity), while the values of the irrelevant dimension (e.g., sex) were held constant. For example, for familiarity judgments, the dimension of sex was held constant, and the block consisted of either familiar and unfamiliar male faces or of familiar and unfamiliar female faces. The purpose of the baseline blocks was to provide a comparison against the filtering block, in which the irrelevant dimension (e.g., sex) was not held constant.

In the filtering block, participants made speeded classifications of the relevant dimension (e.g., familiarity), while the values of the irrelevant dimension (e.g., sex) were randomly assigned. In this block, participants were presented with all four combinations of stimuli dimensions and were asked, as in the baseline blocks, to make speeded classification of one relevant dimension while filtering out random changes in the other, irrelevant dimension.

The ability of participants to focus their attention on one stimulus dimension while ignoring the irrelevant dimension is measured by comparing performance (reaction time [RT] and errors) in the filtering block to performance in the baseline blocks. Worse performance in the filtering block than in baseline is labeled *Garner interference* and represents a failure to selectively attend to one of the two dimensions. Garner interference is an indication that the two dimensions are integral.

Alternatively, equal performance in the filtering block and in baseline testifies to the ability of participants to ignore variations in the irrelevant dimension and indicates that the two dimensions are separable. Garner interference can be found for one dimension (e.g., sex judgments are affected by irrelevant variation in familiarity) but not for the other (e.g., familiarity judgments are not affected by irrelevant variation in sex). Such asymmetries would suggest partial integrality of the two dimensions.

The primary purpose of the experiments described in this article was to use Garner's paradigm to provide converging evidence for the claim that sex judgments and identity judgments are performed by a single route at an early locus of processing. An additional, secondary concern of this article was that of possible influences of applying hairstyle heuristics in making sex judgments. As demonstrated by Goshen-Gottstein and Ganel (2000), the use of hair-included faces in repetition-priming studies can conceal true repetition effects, which, by extension, could falsely be interpreted as a sign of separability. Thus, if hair-included faces are used in Garner's paradigm, participants could apply hairstyle heuristics, ignoring the identity of faces when judging their sex. Hence, it is possible that false separability could be found between sex and identity when hair-included faces are used.

Therefore, we wanted to obtain evidence converging with that in Goshen-Gottstein and Ganel's (2000) study. To this end, we used both edited, hair-deleted faces (Experiments 1 and 4) and complete, hair-included faces (Experiments 2 and 3). Because a common method was applied throughout Experiments 1–4, we first describe the General Method for these experiments. Subsequently, within each experiment, deviations from the General Method are described.

General Method

Participants

Participants with normal or corrected-to-normal vision received course credit for taking part in the experiments. None participated in more than one experiment.

Design and Materials

In all experiments, task (sex judgment or familiarity judgment) and block (baseline or filtering) were manipulated within-subject. The stimuli comprised a factorial combination of Sex (male or female) × Familiarity (familiar or unfamiliar). In the baseline blocks, participants judged one dimension (e.g., sex), while the other dimension was held at a constant value (e.g., both faces were familiar). In the filtering blocks, the participants again judged one dimension (e.g., sex), but the stimuli differed along the irrelevant dimension (e.g., familiarity). Therefore, baseline blocks consisted of only two face photos, and the filtering blocks consisted of all four photos.[4] In all blocks, each photo was presented 10 times in random order, resulting in a total of 20 presentations for each baseline block and 40 presentations for each filtering block.

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[2] The choice of familiarity was also constrained because Garner's paradigm requires factorially crossing identity and sex. Because a single identity cannot belong to two different sexes, a simple decision of identity (*Whose face is this?*) cannot be operationalized in a Garner paradigm.

[3] In many studies, a third block is also used. The third block is a correlated block, in which there is a covariation of the relevant and the irrelevant dimension. However, because the theoretical value of the correlated block has been questioned (Green & Kuhl, 1991; Maddox, 1992; Schweinberger & Soukup, 1998) and because this block is not directly relevant to the single- versus parallel-route controversy, we did not use it in our study.

[4] Because four stimuli were used in the filtering blocks and only two were used in the baseline blocks, it could be argued that Garner interference, if found, is not the result of the integrality of sex and identity but, for example, of the greater task demands for choosing between many alternatives, as compared with choosing between a few alternatives. The results of Experiment 3 invalidate this possible interpretation in that equal performance was found in a condition in which choices were made between many alternatives as compared with a condition in which choices were made between only a few alternatives. Therefore, Garner interference, if found, is a sign of genuine integrality rather than of greater task demands.

A total of four baseline blocks (two for the sex-judgment task: one with only familiar faces and one with only unfamiliar faces; two for the familiarly-judgment task: one with only male faces and one with only female faces) and two filtering blocks (one for the sex-judgment task and one for the familiarly-judgment task) were administered.

Four counterbalanced sets of faces were created, with the constraint that within each set, the three (two baseline and one filtering) familiarity-judgment blocks were positioned one after the other, as were the three sex-judgment blocks. The three sex-judgment blocks were positioned before the familiarity-judgment blocks for half the sets (i.e., two sets) and after the familiarity-judgment blocks for the remaining sets. Within each half, the baseline blocks preceded the filtering block in one set and followed the filtering block in the other set.

The four faces in the stimulus set were of Matti Caspi, a famous Israeli male singer, Achinoam Nini, a famous Israeli female singer, one unfamiliar male, and one unfamiliar female (see Figure 1, for illustrative stimuli). Care was taken to choose faces with neutral expressions. Faces in the stimulus set did not contain facial hair, jewelry, or any other paraphernalia (e.g., glasses) that could help to predict sex.

Using the Adobe Photoshop (Version 5.5) software package, we equated all photos in size, such that they were 7.5 cm long and 5.3 cm wide. Furthermore, the contrast between the faces and the background, which we subjectively determined, was kept constant. The color of the background was set to white. Stimuli were chosen so that except for differences in familiarity, differences between familiar and unfamiliar faces were minimal. That is, we subjectively equated parameters such as age, personal appearance, and skin color between familiar and unfamiliar faces and between male and female faces.

Two versions of the stimulus set were created, one containing complete, hair-included faces (used in Experiments 2 and 3) and the other containing edited, hair-deleted faces (used in Experiments 1 and 4). Edited-face stimuli were created by deleting all the hair and contours (again using Adobe Photoshop). Only the internal facial features and the facial texture remained (see Figure 1 for illustrative stimuli).

In choosing the four faces for the experiment, we were guided by knowledge that sex judgments are made faster than familiarity judgments (e.g., Bruce, 1986; Bruce, Ellis, Gibling, & Young, 1987; Ellis et al., 1990) and are, therefore, perceptually more discriminable. If perceptual discriminability between the two dimensions is not equal, then the processing of the faster dimension (i.e., sex), which is completed before that of the slower one, may interfere with the processing of the slower dimension (i.e., identity). Thus, the processing of identity might be affected by irrelevant changes in sex, resulting in an asymmetric Garner interference. Unfortunately, this asymmetric Garner interference would not represent genuine integrality between the two dimensions but would be an artifact of their different perceptual discriminability (Melara & Mounts, 1993; for a different interpretation, see Schweinberger et al., 1999).

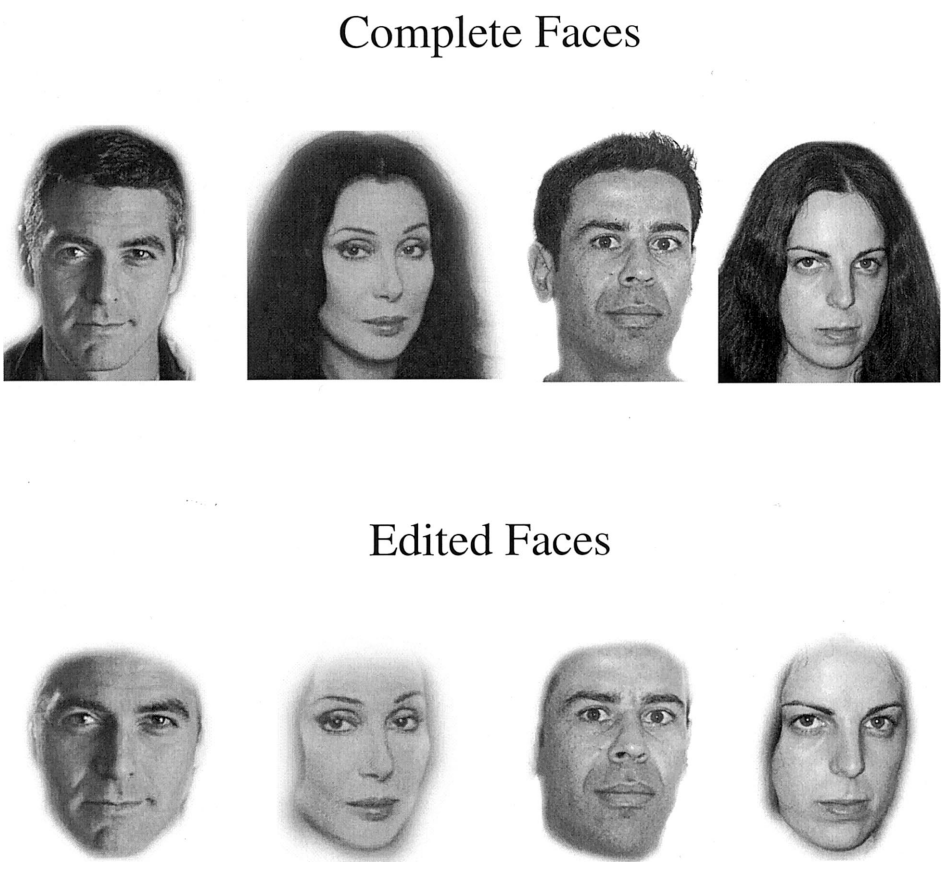

Figure 1. Illustrative stimuli for Experiments 1–4. From left to right: Familiar male, familiar female, unfamiliar male, and unfamiliar female. Complete, hair-included faces (top row) were used in Experiments 2 and 3, and edited, hair-deleted faces (bottom row) were used in Experiments 1 and 4. Illustrative familiar faces rather than the actual faces that were used are shown, because the actual familiar faces were famous in Israel alone. Individuals whose faces appear here as unfamiliar male and unfamiliar female gave signed consent for their likenesses to be published in this study.

Although this built-in difference in discriminability between identity and sex judgments could, in theory, be compensated for by a careful selection of facial stimuli (e.g., by selecting faces whose sex is difficult to classify), such a selection would reduce the external validity of the experiment. Still, to ensure high levels of correct performance on our task, we chose, on the basis of prior data (Goshen-Gottstein & Ganel, 2000), four faces for which participants could at least perform highly accurate (i.e., 99.7%) familiarity judgments while maintaining similar response latencies for sex judgments between familiar and unfamiliar faces.

Even if discriminability between sex and familiarity is not equated and the discriminability of sex is greater than that of familiarity, Garner interference in which sex (the easier dimension) is affected by familiarity (the harder dimension) would still describe a genuine interference of the dimensions rather than be a result of their different discriminability and would support the single-route hypothesis.

Procedure

Participants were individually tested and were equally divided into one of the four counterbalanced sets of faces. First, they were told that during the experiment, they would be asked to perform several face-relevant tasks as quickly and accurately as they could. Next, all four photos were shown so that participants would be acquainted with them. Stimuli were presented on a 17-in. screen of a Pentium III class computer.

The experimental blocks were then administered. In each block, participants were asked to make speeded classification of either the sex (male or female) or the familiarity (familiar or unfamiliar) of faces. Each block was preceded by eight practice trials for the baseline blocks (four random repetitions of each stimulus) and 16 practice trials for the filtering blocks. The experimental trials immediately followed.

Each trial began with a blank, white screen presented for 1 s and was immediately followed by a face photo, located at the center of the screen. The face remained on the screen until a response was recorded, at which point the stimulus disappeared. The next trial began 2 s after the participant's response. Response keys were the left and right buttons of a Cedrus Corporation four-key response box. The left response key was assigned to *female* and *unfamiliar* judgments and the right response key was assigned to *male* and *familiar* judgments, depending on the block. The blocks were separated by 1-min breaks, in which participants were asked to patiently wait for the next part of the experiment.

Experiment 1

In Experiment 1, only edited, hair-deleted face photos were used so that attention would be directed to the critical, interior facial features, thereby eliminating the use of possible hairstyle heuristics (e.g., Goshen-Gottstein & Ganel, 2000). According to the parallel-route hypothesis (Bruce & Young, 1986; Burton et al., 1990), sex and identity should be separable dimensions and, Garner interference should not emerge. However, we predicted that Garner interference should emerge for sex and identity, because these two dimensions are processed via the same route. Hence, we predicted sex and identity to appear as integral dimensions.

Method

A total of 20 Tel-Aviv University undergraduates, 5 men and 15 women, participated in the experiment. Participants were administered the version of the stimulus set that contained edited, hair-deleted photos.

Results and Discussion

For each participant, mean RTs, expressed in milliseconds, were calculated from the distribution of correct responses, with skewness reduced by eliminating outliers that were 2.5 standard deviations above the mean, for each of the four (2 tasks $\times$ 2 blocks) conditions. A total of 2.1% of the responses were eliminated for this reason. The means were then averaged across the 20 participants in the four within-subject conditions. Table 1 displays the means and mean percentages of error for the analysis.

For this and subsequent analyses, the data were submitted to an analysis of variance (ANOVA) with task (familiarity judgment or sex judgment) and block (baseline or filtering) as within-subject variables. For all experiments, only effects achieving significance at the $\alpha = .05$ level are reported. Unless otherwise noted, all hypotheses were treated as two-tailed.

Examination of the results revealed that RTs for sex judgments were 18 ms shorter than RTs for familiarity judgments. This main effect of task was significant, $F(1, 19) = 29.14$, $MSE = 1{,}243$, $p < .05$. However, equal discriminability was still kept between the two dimensions, as evidenced by the insignificant 14-ms difference between the baseline blocks of the two dimensions, $t(19) = 1.66$, $p > .05$.

More important, the results, as can be seen in Table 1, show a symmetric Garner-interference effect.[5] RTs in the filtering block were longer than RTs in the baseline blocks by 48 ms for sex judgments and by 55 ms for familiarity judgments. Indeed, the main effect for block was significant, $F(1, 19) = 129.45$, $MSE = 417$, $p < .0001$, with Garner interference observed for both sex judgments, $t(19) = 10.54$, $p < .0001$, and familiarity judgments, $t(19) = 7.09$, $p < .0001$. The different magnitude of interference for the two tasks, however, was inconsequential, as revealed by the insignificant two-way interaction between block and task, $F(1, 19) = 0.56$, $MSE = 404$.

Examination of the error rates confirmed the pattern found for RTs and revealed a Garner interference of 1.2% fewer errors in the baseline as compared with the filtering blocks, $F(1, 19) = 7.36$, $MSE = 4.68$, $p < .05$. All other effects failed to achieve significance.

The most important result of Experiment 1 was the symmetric Garner-interference effect found for both familiarity and sex judgments that was evident for both latency and accuracy data. The failure to selectively attend to the dimension of identity without being affected by changes in sex as well as the failure to selectively attend to the dimension of sex without being affected by changes in identity support the notion that these two dimensions are processed together in an early cognitive stage. Therefore, the finding that the dimensions of identity and sex are integral dimensions confirms the predictions of the single-route hypothesis for sex and identity and extends prior results to account not only for a

[5] Some studies suggest that women are better than men at recognizing faces, because they process faces in a more holistic manner (for a review, see Shepherd, 1981). Because most of our participants were women, we wished to exclude the possibility that our Garner interference effects were due to a gender bias. To achieve this, we performed an additional analysis that included only the results of the 11 male participants across Experiments 1, 2, and 4 (in these experiments, Garner interference effects emerged). The results confirmed that the effects were not due to a gender bias; a significant Garner interference effect of 51 ms was found for familiarity judgments, $t(10) = 3.57$, $p < .01$. A significant Garner interference effect (58 ms) also emerged for sex judgments, $t(10) = 4.98$, $p < .001$.

Table 1
Experiment 1: Mean Reaction Times (RTs, in Milliseconds; With Standard Errors) and Percentages of Error in the Baseline and Filtering Blocks for Familiarity and Sex Judgments of Edited, Hair-Deleted Faces

	Baseline		Filtering		Garner interference	
Task	RT	% error	RT	% error	RT	% error
Familiarity	434 (11)	2.0	489 (12)	4.0	55	2.0
Sex	420 (9)	2.8	468 (10)	3.3	48	0.5
Overall	427 (10)	2.4	479 (11)	3.6	52	1.2

Note. Garner interference was calculated by subtracting mean performance in the baseline blocks from performance in the filtering block.

mnemonic interaction between sex and identity but also for a perceptual interaction between the processing of these dimensions.

Experiment 2

The finding that identity and sex are integral dimensions (Experiment 1) and the repetition-priming effects found for sex judgments (Goshen-Gottstein & Ganel, 2000, Experiments 1, 4, and 5) provide converging evidence for the single-route hypothesis. In both this study and Goshen-Gottstein and Ganel (2000), the effects were obtained when edited, hair-deleted stimuli were used. In this experiment, we presented participants with hair-included faces to explore our secondary hypothesis regarding the necessity of using edited, hair-deleted faces as the experimental stimuli. In the repetition-priming task of Goshen-Gottstein and Ganel, repetition effects did not emerge for sex judgments when hair-included faces were used (Goshen-Gottstein & Ganel, 2000, Experiments 2 and 4). Our interpretation of this finding was that when presented with complete faces, participants resorted to using hairstyle heuristics. Attention was, therefore, drawn away from the interior, crucial facial features, thereby not enabling the reactivation of FRUs.

If our interpretation is correct, then the inclusion of hair in the facial stimuli should have a similar effect on the perceptual integrality between sex (for which processing would now be based on external features) and identity (for which processing would still be based on internal facial features). Therefore, we predicted that if familiarity judgments are based on information that is available from the internal facial features, whereas sex judgments are based on the information that is available in the hairstyle, then (false) separability would be found between the dimensions of identity and sex. We tested this hypothesis in Experiment 2.

Method

A total of 20 university undergraduates, 3 men and 17 women, participated in this experiment. The method was identical to that used in Experiment 1, except that the complete, hair-included versions of the photos were presented.

Results and Discussion

For each participant, mean RTs (in milliseconds) were calculated as in Experiment 1, eliminating 2% of outliers. Table 2 displays these means and the mean percentages of error.

Examination of the results revealed that RTs for sex judgments were 30 ms shorter than RTs for familiarity judgments. This main effect of task was significant, $F(1, 19) = 8.63$, $MSE = 2{,}043$, $p < .01$. However, as in Experiment 1, equal discriminability was still kept between the two dimensions, as evidenced by the insignificant 25-ms difference between the baseline blocks of the two dimensions, $t(19) = 2.04$, $p > .05$.

Most important, an unexpected Garner-interference effect of 51 ms was found. This effect was evident for both familiarity judgments (55 ms) and sex judgments (47 ms). Indeed, the main effect of block was significant, $F(1, 19) = 28.79$, $MSE = 1{,}809$, $p < .0001$, and was observed for both familiarity judgments, $t(19) = 5.14$, $p < .0001$, and sex judgments, $t(19) = 12.25$, $p < .01$. However, the different magnitude of Garner interference found for sex judgments and familiarity judgments as assessed by the two-way interaction between block and task was insignificant, $F(1, 19) = 0.33$, $MSE = 1{,}150$, $p > .1$.

Examination of the error data revealed neither significant main effects nor a significant interaction between task and block variables. The possibility that speed–accuracy trade-offs could account for the unexpected results must, therefore, be dismissed.

In contrast to our prediction, although hair-included faces were used, a robust, symmetric Garner-interference effect emerged in Experiment 2. Indeed, this pattern of results was almost identical to that found in Experiment 1, in which hair-deleted faces were used. Thus, the dimensions of identity and sex were found to be integral in both Experiments 1 and 2.

Although not predicted, this result actually supports our primary hypothesis in that it suggests that sex and identity are processed via a single route. Thus, the dimensions of sex and identity could be found to be dimensions so closely integrated that they cannot be separated, even when parameters that have proven effective in eliminating effects in other paradigms are chosen (i.e., the inclusion of hair in repetition-priming tasks). However, this integrality between the dimensions of sex and identity may imply that hairstyle heuristics do not always mediate sex judgments (which, although inconsistent with our earlier findings, is only secondary to our present concerns).

Yet before accepting this result of integrality as challenging our secondary hypothesis, an alternative interpretation should be considered. Our findings show only that the inclusion of hair in facial stimuli does not separate, as we had presumed it does, between

Table 2
Experiment 2: Mean Reaction Times (RTs, in Milliseconds; With Standard Errors) and Percentages of Error in the Baseline and Filtering Blocks for Familiarity and Sex Judgments of Complete, Hair-Included Faces

	Baseline		Filtering		Garner interference	
Task	RT	% error	RT	% error	RT	% error
Familiarity	392 (14)	2.1	447 (10)	3.8	55	1.7
Sex	367 (7)	3.2	413 (15)	2.9	47	−0.3
Overall	379 (11)	2.7	430 (12)	3.3	51	0.6

Note. Garner interference was calculated by subtracting mean performance in the baseline blocks from performance in the filtering block.

processing of identity and sex. This absence of separability between identity and sex does not necessarily imply, however, that hairstyle heuristics do not mediate sex judgments. An alternative interpretation of our finding is that hairstyle heuristics mediate not only sex judgments but, under some circumstances, even familiarity judgments. According to this alternative, both the single-route hypothesis and our understanding of hairstyle heuristics may turn out to be correct after all.

This alternative is based on the realization that when only four faces are repeatedly presented (40 times: 10 presentations for each of the four blocks) in the context of a laboratory experiment (i.e., Experiments 1 and 2), participants may learn to associate a particular hairstyle with a specific person and use the information that is available in a particular hairstyle (or another superficial feature) to help them make speeded judgments of familiarity.

Indeed, a brief examination of Figure 1 reveals that each of the four faces has a hairstyle that may be sufficiently unique so as to guide judgments of familiarity. We suggest, therefore, that in Experiment 2, familiarity judgments as well as sex judgments may have been based on the hairstyle of faces. If both judgments were based on hairstyle, then it is reasonable for the dimensions of sex and familiarity to be integral. This integrality, however, would be fake integrality, in the sense that it was not genuine but rather was an artifact of the particular experimental design, wherein only four faces were repeatedly presented, and hairstyle could help in judging familiarity. Experiments 3 and 4 were designed to explore this interpretation by using Garner's paradigm with the presentation of many faces. Moreover, the presentation of many faces also served to enhance the external validity of our findings.

Experiments 3 and 4

To overcome the possibility that participants based familiarity judgments on hairstyle, we used a modified Garner paradigm. Instead of using only a single face in each of the four possible Sex × Familiarity combinations (familiar male, familiar female, unfamiliar male, and unfamiliar female), we now used 10 faces in each of the four combinations, for a total of 40 faces. To enable a pure comparison with Experiments 1 and 2, we applied the modified paradigm to both hair-included faces (Experiment 3) and hair-deleted faces (Experiment 4).

For the hair-included faces (Experiment 3), the large number of faces should, without a doubt, make it very difficult to learn to associate a specific hairstyle with a specific person. Therefore, a possible benefit to familiarity judgments from the information contained in hairstyle would be improbable, and familiarity judgments would be primarily based on internal facial features. Hairstyle heuristics, however, would still be used for making sex judgments (e.g., Goshen-Gottstein & Ganel, 2000). Because familiarity judgments alone would rely on internal facial features, we predicted that Garner interference would not emerge for the hair-included faces. Sex and identity were, therefore, predicted to appear as separable dimensions when many hair-included faces were presented in the modified paradigm.

As for the hair-deleted faces (Experiment 4), integrality between identity and sex was predicted to emerge, because judgments regarding both dimensions would again be based on the internal faces features. In summary, a finding of separability for hair-included faces with integrality for hair-deleted faces would support the single-route hypothesis as well as validate the notion that heuristics can bring about hair-based processing and can produce a false separability.

Another equally important purpose of Experiments 3 and 4 was to enhance the external validity of the results of Experiments 1 and 2. One may argue that the use of only a single photo for each Sex × Familiarity combination reduces the external validity of the experiment. Although almost all Garner studies also used only one exemplar for each dimensional combination (e.g., Algom et al., 1993; Garner & Felfoldy, 1970; Pansky & Algom, 1999; Schweinberger et al., 1999; Schweinberger & Soukup, 1998), the use of only a single exemplar could, nevertheless, elicit effects that are idiosyncratic to the processing of the particular stimulus. Such idiosyncratic processing would have been even more likely to occur for our facial stimuli, because their visual complexity was greater than that in standard Garner experiments (e.g., simple geometrical figures such as lines, circles, and squares). Therefore, the use of only one stimulus for each dimensional combination could have failed to represent the actual processing that occurs. Hence, a demonstration of Garner interference between the dimensions of familiarity and sex (Experiment 4, hair-deleted faces) when 40 photos are presented should greatly enhance the external validity of our previous results.

Method

A total of 40 Tel-Aviv University undergraduates, 8 men and 32 women, participated in Experiments 3 and 4, half in each experiment. Experiments 3 and 4 were identical, except that hair-included faces were used in Experiment 3, and hair-deleted faces were used in Experiment 4.

The method was identical to that used in Experiments 1 and 2, except that 36 new faces were added (nine for each Sex × Familiarity combination) to the original stimulus set of four faces, for a total of 40 faces (10 for each Sex × Familiarity combination). The newly added faces were equated with the four original faces for parameters such as age, personal appearance, and skin color, as we subjectively determined.

For each of the baseline blocks, 18 new faces were added, and all 36 faces were added to the filtering blocks. Thus, a total of 20 faces were used in each baseline block, and a total of 40 faces were used in each filtering block. For example, the first baseline block for sex judgments consisted of 10 familiar male faces (1 original and 9 new) and 10 familiar female faces, whereas the second baseline block for sex judgments consisted of 10 unfamiliar male and 10 unfamiliar female faces.

To minimize changes from Experiments 1 and 2, we repeated the original four faces 10 times within each block. To reduce possible effects of fatigue, we repeated the new faces only twice within each block.

Results

For each participant, mean RTs (in milliseconds) were calculated as in Experiments 1 and 2. To equate this analysis to those of Experiments 1 and 2, we first analyzed only the data of the original four faces. Table 3 displays the means and mean percentages of error for the analysis performed on the original four faces, and Table 4 displays these means for the entire stimulus set.

Results for hair-included faces (Experiment 3). A total of 1.8% of the responses of Experiment 3 were eliminated as outliers. Examination of the data revealed that RTs for sex judgments were 41 ms shorter than RTs for familiarity judgments. The main effect of task was significant, $F(1, 19) = 23.47$, $MSE = 1{,}484$, $p < .001$. More important, a difference in discriminability between the two

Table 3
Experiments 3 (Complete Faces) and 4 (Edited Faces): Mean Reaction Times (RTs, in Milliseconds; With Standard Errors) and Percentages of Error in the Baseline and Filtering Blocks for the Four Stimuli Used in Experiments 1 and 2

	Baseline		Filtering		Garner interference	
Task	RT	% error	RT	% error	RT	% error
			Complete faces			
Familiarity	529 (19)	4	531 (12)	3.1	2	−0.9
Sex	480 (18)	2.6	497 (15)	1.5	17	−1.1
Overall	504 (17)	3.3	514 (18)	2.3	10	−1.0
			Edited faces			
Familiarity	569 (15)	1.9	597 (18)	1.2	28	−0.7
Sex	498 (12)	1.5	532 (20)	1.8	34	0.3
Overall	534 (12)	1.7	564 (19)	1.5	31	−0.2

Note. The complete, hair-included faces were used in Experiment 3, and the edited, hair-deleted faces were used in Experiment 4. Garner interference was calculated by subtracting performance in the baseline blocks from performance in the filtering block. See Table 4 for an analysis across the entire stimulus set.

tasks was found in the significant difference of 49 ms between the baseline blocks of the two tasks, $t(19) = 5.09$, $p < .0001$.

Most important, there was only a small, 10-ms difference between responses in baseline and filtering blocks for complete faces. As predicted, this difference did not achieve significance, $F(1, 19) = 0.96$, $MSE = 2{,}101$, $p > .1$. The Garner-interference effect was negligible for both familiarity judgments (2 ms) and sex judgments (17 ms). Specific comparisons confirmed the absence of Garner interference for familiarity judgments, $t(19) = 0.15$, $p > .1$, and for sex judgments, $t(19) = 1.68$, $p > .1$. The different magnitude of interference for the two tasks was insignificant, as revealed by the results of the two-way interaction between block and task, $F(1, 19) = 1.01$, $MSE = 1{,}204$, $p > .1$.

Examination of the error data revealed neither main effects nor an interaction between the task and block variables, thus eliminating the possibility that speed–accuracy trade-offs could account for the lack of Garner interference. In summary, as predicted, the results demonstrate that the dimensions of sex and identity are (falsely) separable when hair-included faces are used in the modified Garner paradigm.

Results for hair-deleted faces (Experiment 4). A total of 1.7% of the responses of Experiment 4 were eliminated as outliers. Examination of the data revealed that RTs for sex judgments were 68 ms shorter than RTs for familiarity judgments. The main effect of task was significant, $F(1, 19) = 29.14$, $MSE = 1{,}243$, $p < .0001$. As in Experiment 3, a difference in discriminability between the two tasks was found in the significant difference of 71 ms between the baseline blocks of the two tasks, $t(19) = 5.89$, $p < .0001$.

Most important, a Garner-interference effect of 30 ms was found for edited faces. This effect was evident for both familiarity judgments (28 ms) and sex judgments (34 ms). The critical main effect of block was significant, $F(1, 19) = 8.99$, $MSE = 2{,}089$, $p < .01$. Specific comparison revealed that this Garner interference was evident for familiarity judgments, $t(19) = 2.28$, $p < .05$, as well as for sex judgments, $t(19) = 2.71$, $p < .05$. The different magnitude of interference for the two tasks was insignificant, as revealed by the results of the two-way interaction between block and task, $F(1, 19) = 0.21$, $MSE = 908$, $p > .1$.

Examination of the error data revealed neither main effects nor an interaction between task and block variables, thus eliminating the possibility that speed–accuracy trade-offs could account for the Garner interference effect. In summary, as predicted, the results demonstrate that the dimensions of sex and identity are genuinely integral and appear as such in both classic Garner (Experiment 1) and modified Garner (Experiment 4) paradigms.

Analysis across Experiments 3 (complete faces) and 4 (edited faces). Because our arguments are based on a significant Garner-interference effect in Experiment 4 accompanied by a nonsignificant effect in Experiment 3, we further analyzed our results as collected from a single design, with presentation format (edited or complete) as a between-subjects variable and block (baseline or filtering) and task (familiarity judgment or sex judgment) as within-subject variables. We corrected for the effects of counterbalancing, as recommended by Pollatsek and Well (1995). For the sake of brevity, we do not report main effects when these enter into significant interactions.

A significant two-way interaction was found between presentation format and task, $F(1, 32) = 4.27$, $MSE = 1{,}647$, $p < .05$. This interaction was the result of the 23 ms shorter processing of complete as compared with edited faces in sex judgments, which was smaller than the 53 ms found for familiarity judgments. This interaction is probably the result of the relative processing times needed to complete the two tasks. Effects of presentation format (edited or complete) were less likely to emerge in the task that participants completed more quickly (sex judgment) than in the slower task (familiarity judgment).

More important, as can be seen in Table 3, the effect of Garner interference for edited faces (Experiment 4) was 20 ms larger than the (insignificant) effect of Garner interference for complete faces (Experiment 3). The significant two-way interaction between presentation format and block confirmed that this difference was significant, $F(1, 32) = 3.61$, $MSE = 1{,}174$, $p < .05$, one-tailed. All other two-way and three-way interactions were not significant.

Analysis of the entire stimulus set: Verifying the external validity of the results. An important motivation for conducting Experiments 3 and 4 was to extend the external validity of Experiments 1 and 2, in which only four face photos were used. Indeed, the Garner interference that emerged in Experiment 4 (accompanied by the null interference in Experiment 3) confirmed that Garner interference between the dimensions of familiarity and sex was evident when a large number of facial stimuli were used. However, to allow an effective comparison between the results of Experiments 3 and 4 with those of Experiments 1 and 2, we have so far analyzed only responses for the four faces that composed the original stimulus set. It could still be argued, however, that although the *design* of Experiments 3 and 4 had answered the question of external validity, the *analysis* of the results of these experiments (that was still based on only four stimuli) was insufficient to establish external validity. To establish external validity, we further analyzed the results of Experiments 3 and 4, and included responses to the entire stimulus set (all 40 photos) in this analysis.

The analysis was similar to that of Experiments 3 and 4, with the exception that the data from all 40 faces of the stimulus set were analyzed. Table 4 displays the means and mean percentages of error for this analysis.

As can be seen in Table 4, the overall pattern of results was almost identical to the pattern of results for the four original stimuli (see Table 3). The only marked differences were the elevated RTs and error rates for the entire as compared with the original stimulus set (entire set: mean RT = 579.8 ms, error rate = 4.2%; original set: mean RT = 529 ms, error rate = 2.2%). This difference can be explained in that the newly added exemplars were repeated only twice in each experimental block, compared with the original four faces that were repeated 10 times in each block (see the *Method* section of Experiments 3 and 4). The original facial stimuli may have resulted in more efficient processing, due to larger repetition-priming effects that may have emerged because of the increased number of repetitions of the original facial stimuli.

The results from Experiments 3 and 4 were analyzed as collected from a single design, with presentation format (edited or complete) as a between-subjects variable and block (baseline or filtering) and task (familiarity judgment or sex judgment) as within-subject variables. As in the previous analysis, effects of counterbalancing were corrected as recommended by Pollatsek and Well (1995), and for the sake of brevity, we do not report main effects when these enter into significant interactions.

As can be seen in Table 4, the effect of Garner interference for edited faces (Experiment 4) was 51 ms larger than the (insignificant) effect of Garner interference for complete faces (Experiment 3). The significant two-way interaction between presentation format and block confirmed that this difference was significant, $F(1, 32) = 8.98$, $MSE = 2{,}902$, $p < .01$. Further analysis confirmed that the 57-ms Garner interference for edited faces was significant, $F(1, 32) = 22.36$, $MSE = 2{,}026$, $p < .01$, as compared with an insignificant Garner interference (6 ms) for complete faces, $F(1, 32) = 0.23$, $MSE = 691$, $p > .1$. All other interactions were not significant. Examination of the error data revealed neither main effects nor an interaction between task and block variables.

Table 4
Experiments 3 (Complete Faces) and 4 (Edited Faces): Mean Reaction Times (RTs, in Milliseconds; With Standard Errors) and Percentages of Error in the Baseline and Filtering Blocks for the Entire Stimulus Set

	Baseline		Filtering		Garner interference	
Task	RT	% error	RT	% error	RT	% error
			Complete faces			
Familiarity	595 (22)	4.7	601 (20)	4.8	6	0.1
Sex	505 (19)	2.4	510 (19)	3.5	5	1.1
Overall	550 (20)	3.6	556 (22)	4.2	6	0.6
			Edited faces			
Familiarity	651 (24)	3.4	693 (35)	5.0	42	1.6
Sex	505 (14)	1.8	576 (32)	7.9	71	6.1
Overall	578 (21)	2.6	635 (32)	6.4	57	3.8

Note. The complete, hair-included faces were used in Experiment 3, and the edited, hair-deleted faces were used in Experiment 4. Results are based on responses to the entire set of 40 (10 for each Sex × Familiarity combination) face photos. Garner interference was calculated by subtracting performance in the baseline blocks from performance in the filtering block.

Together, these results correspond to the results of the earlier analysis of Experiments 3 and 4 that included the responses for the four original faces alone. These results, therefore, extend the external validity of the previous experiments and provide more compelling support for the single-route hypothesis.

Discussion

The results of Experiment 4 confirmed our primary hypothesis that sex and identity judgments are processed together. Thus, in support of the single-route hypothesis, we found that sex and identity were integral dimensions. The results of Experiment 3 confirmed our secondary hypothesis that hairstyle heuristics can mediate sex judgments. It seems that there are, in fact, unique circumstances under which identity and sex are falsely perceived as separable—in particular, when hair-heuristics are used (for a similar conclusion, see Goshen-Gottstein & Ganel, 2000). This separability, however, must be attributed to the use of hairstyle heuristics that overrides the critical processing of the interior facial features. Indeed, the results of Experiment 4 showed that when hair-deleted faces were used, for which processing could not be based on hairstyle, the dimensions of sex and identity were found, once again, to be integral.

In Experiments 3 and 4, the dimensions of identity and sex were not equally discriminable, with judgments of sex easier to make than judgments of familiarity. It could be argued that this difference in discriminability can account for the Garner interference from sex (the easier dimension) to judgments of identity (the more difficult dimension). Hence, the interference from the dimension of sex to familiarity judgments might be an artifact of the difference in discriminability.

Yet the easier discriminability of the dimension of sex than that of identity cannot account for the Garner interference from the dimension of identity (the more difficult dimension) to the judgments of sex (the easier dimension). Therefore, the interference from the dimension of identity to the judgments of sex can be considered as a genuine interference effect. This genuine Garner-interference effect cannot be explained by the parallel-route hypothesis.

Moreover, there are at least three reasons for believing that even the interference from sex (the more discriminable dimension) to familiarity (the less discriminable dimension) represents a genuine and not an artificial Garner-interference effect. First, Schweinberger et al. (1999) showed that even when unequal discriminability exists between two face-relevant dimensions (identity and expression), Garner interference from the more discriminable dimension (identity) to the less discriminable dimension (expression) still represents a genuine interference effect. Schweinberger et al. reached this conclusion by directly manipulating discriminability between identity and expression and showing that this manipulation did not affect the magnitude of the Garner interference from identity to expression. By extension, it is not too far-fetched to assume that the Garner interference (Experiment 4) between another pair of face-related dimensions (i.e., identity and

sex) also represents a genuine interference effect and is not a result of the differences in discriminability between the two dimensions.

The second reason for believing that the interference from the dimension of sex to familiarity judgments is genuine is that if the difference in discriminability was the cause of Garner interference, then equal discriminability should result in an absence of Garner interference. However, the results of Experiments 1 and 2 demonstrate the dimensions of sex and identity were equally discriminable, yet irrelevant variations of sex still interfered with judgments of familiarity. Finally, if the difference in discriminability was the cause of Garner interference, then we would have expected this interference to also be found in Experiment 3 (hair-included faces) in which unequal discriminability was found. In Experiment 3, however, Garner interference was absent.

In conclusion, we argue that not only is the interference from the dimension of identity (the less discriminable dimension) to judgments of sex (the more discriminable dimension) a genuine effect but even the interference from the dimension of sex to familiarity judgments represents a genuine Garner-interference effect. Both effects, therefore, confirm the predictions of the single-route hypothesis and are difficult to reconcile with a theory that assumes that sex and identity are processed via different routes (e.g., Bruce & Young, 1986).

General Discussion

According to the parallel-route hypothesis (e.g., Bruce & Young, 1986) identity and sex are computed in distinct cognitive (and neuroanatomical) routes. Therefore, Garner interference should not be found between these dimensions and separability is expected. According to the single-route hypothesis (Goshen-Gottstein & Ganel, 2000), the dimensions of identity and sex are processed by a single route and should, therefore, be integral.

The primary conclusion to emerge from the set of experiments that is described in this article is that identity and sex are integral dimensions. The results of Experiments 1, 2, and 4 strongly support this idea by demonstrating a robust, symmetric Garner-interference effect for which sex judgments could not be made without being affected by irrelevant variations in familiarity, and familiarity judgments could not be made without being affected by irrelevant variations in sex (however, see discussion of Experiment 2). Therefore, the integrality between identity and sex that was found in this study strongly supports the single- rather than the parallel-route hypothesis for sex and identity.

Despite the strong support for the single-route hypothesis that was found in our experiments, one might still argue that a radical version of functional independence, as described by Bruce and Young (1986), is incorrect, but that a less radical version may still be plausible. For example, one might suggest that identity and sex are processed separately, as described by the parallel-route hypothesis, yet interact at an initial stage of processing.

This interpretation, however, is less probable in light of the converging behavioral and neuroanatomical evidence that supports the notion that identity and sex decisions are made by a single route even during later, memory-based stages of processing. The finding of integrality must be taken together with Goshen-Gottstein and Ganel's (2000) study, which demonstrated, at a behavioral level, a mnemonic influence on sex-relevant processing that converged with two independent demonstrations of mnemonic influences on the activation of brain areas during sex judgments (Dubois et al., 1999; Rossion et al., 2001). The current results, therefore, extend these earlier findings by showing that identity and sex are processed together not only at late (mnemonic) stages of processing but even at early (perceptual) stages of information processing.

Thus, the findings from the different paradigms have shown that sex and identity are initially perceived as one and are also processed in harmony at later, mnemonic stages of processing. It seems unlikely that somewhere amid these stages, information regarding sex and identity diverges only to converge again at a later point in time. Therefore, we argue that sex and identity are processed together throughout the entire range of information processing, or at least from initial perception to the FRUs. Still, we cannot entirely dismiss the possibility that our data disprove only the radical version of the parallel-route hypothesis in which the routes are completely independent. If this is the case, then our data are important in that they show that if two routes do indeed exist, they must have strong interconnections between them.

Although sex and identity seem to be processed in harmony throughout the entire range of information processing, this may not be the case regarding the processing of identity and other face-classification dimensions, such as expression and facial speech (see the introduction). Two studies have examined the relationship between identity and expression (and facial speech) using Garner's paradigm. Schweinberger et al. (1999) and Schweinberger and Soukup (1998) reported only a partial integrality between expression (and facial speech) and identity. Garner interference was not found from the dimension of expression and facial speech to the dimension of identity. The absence of Garner interference suggests that expression and identity are computed by parallel routes. This finding converges, therefore, with neuropsychological (Campbell et al., 1986; Humphreys et al., 1993; Tranel et al., 1988; Young et al., 1993), neuroanatomical (Breiter et al., 1996; Calvert et al., 1997), and single-cell recording studies (Perrett & Mistlin, 1990).

Yet both Schweinberger et al. (1999) and Schweinberger and Soukup (1998) found some evidence of an interaction between expression judgments and face identification. Both studies reported Garner-interference effects from the dimension of identity to judgments of expression, with irrelevant variations in identity negatively affecting judgments of expression. As these authors concede, this finding cannot be easily accounted for by a radical version of parallel processing of expression and identity, in that it shows that identity influences the way expression is perceived (for a similar conclusion, see Haxby et al., 2000).

Recently, we too have applied Garner's speeded-classification task to test the relationship between identity and expression (Ganel & Goshen-Gottstein, 2002). In contrast with both Schweinberger et al. (1999) and Schweinberger and Soukup (1998), who examined only the relationship between expression and the identity of unfamiliar faces, we examined the relationship between expression and the identity of unfamiliar as well as familiar faces.

Contrary to the predictions of the parallel-route hypothesis, we found larger Garner interference from identity to expression for familiar faces, as compared with unfamiliar faces, which suggests that familiarity with faces (which is one aspect of their identity) modulates the way expressions are perceived. More important, Garner interference for familiar faces was bidirectional and was found not only from identity to expression but also from expres-

sion to identity. Thus, at least for familiar faces, the dimensions of identity and expression seem to be integral.

The finding from Garner's paradigm that suggests that the processing of expression is not entirely independent from face identification is accompanied by further behavioral data (Baudouin, Gilibert, Sansone, & Tiberghien, 2000), as well as data from single-cell recordings in monkeys (Sugase et al., 1999). Together, these findings suggest that the systems that process identity and expression may be interconnected to some degree. Therefore, the parallel-route hypothesis—at least in its radical form that suggests a complete functional and neuroanatomical separability—must not be categorically accepted, even when regarding the apparent independent processing of expression and identity. Additional data from behavioral as well as from neuroanatomical studies must be gathered to specify the exact locus of interaction between expression and identity judgments.

As for the processing of sex and identity, the current results, together with the results of other studies (Calder et al., 2001; Dubois et al., 1999; Goshen-Gottstein & Ganel, 2000; Rossion et al., 2001) indicate that these facial dimensions are processed by a single system at both a functional level of description and at a neuroanatomical level. We suggest that the design of the face-recognition system may have actually evolved to reflect the way that different classes of face-relevant information are initially perceived, as in the particular case of the dimensions of sex and identity. Our results establish that these dimensions are intrinsically bound together so that the processing of one dimension necessarily involves the processing of the other. It seems that dimensions that are bound together during early stages of information processing as revealed in the present study are still processed together during later stages of cognitive analysis, as revealed in the pattern that emerges in memory-based paradigms. The sex of a face seems, therefore, to be an emergent property of its identity.

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