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Perception of facial attractiveness requires some attentional resources: implications for the "automaticity" of psychological adaptations

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Abstract

Traditional criteria for modularity assert that perceptual adaptations for processing evolutionarily important stimuli should operate "automatically" in the sense of requiring no central attentional resources. Here, we test the validity of this automaticity criterion by assessing the attentional demands of a well-studied perceptual adaptation: judgment of facial attractiveness. We used locus-of-slack logic in a dual-task psychological refractory period paradigm, where Task 1 was a speeded judgment of tone pitch (low vs. high), and Task 2 was a speeded judgment of whether a face was attractive or unattractive, with the Task-2 judgment manipulated to have a low or a high difficulty level. In two studies (N=36 and N=73 female participants; 384 trials each), the Task 2 difficulty effects were additive with stimulus-onset asynchronies (100, 300, 500 or 900 ms) on Task 2 response times. According to the locus-of-slack logic, this result implies that participants could not discriminate facial attractiveness level, while their central attentional resources were still occupied by Task 1. If the human capacity for perceiving facial attractiveness—a premier example of an adaptation—does not show automaticity in this sense, automaticity may not be a useful criterion for identifying psychological adaptations.

Keywords: Facial attractiveness; Modularity; Automaticity; Dual task; Attention; Cognition; Chronometrics

1. Introduction

The human capacity to perceive facial attractiveness is one of the most exhaustively researched domains in all of evolutionary psychology and constitutes a premier example of psychological adaptation (Perrett, 2010; Rhodes & Zebrowitz, 2002). It also provides an excellent opportunity to test different modularity criteria proposed for psychological adaptations. Just before evolutionary psychology coalesced as a science, Fodor (1983) proposed that every psychological adaptation should have the following criteria of modularity: mandatory operation (automaticity), domain specificity, encapsulation, inaccessibility to consciousness, speed, shallow outputs, fixed brain location, and characteristic breakdown patterns. These Fodorian criteria inspired the "massive modularity" view of the mind that dominated evolutionary psychology from around 1990 onward and led to much research on which candidate adaptations fit which criteria. For example, DeSteno, Bartlett, Braverman, and Salovey (2002) took the automaticity criterion seriously to test putative adaptations for sexual jealousy. Using a dual-task paradigm, they examined whether sex differences in a jealousy judgment could occur independently of the cognitive load imposed by a concurrent digit-string memory task. They found that the memory task reduced sex differences in forced-choice judgments about whether sexual vs. emotional infidelity would be more upsetting and inferred that the sex difference in jealousy judgment was not fully automatic. Based on these results, they speculated that the sex difference in jealousy judgment does not reflect psychological adaptation.

Many of Fodor's criteria have come under fire in recent years. For example, the automaticity criterion was challenged by Pinker (1997), Sperber (2005), Barrett and Kurzban (2006) and others as irrelevant or misconceived. Barrett, Frederick, Haselton, and Kurzban (2006) argued specifically against DeSteno et al. (2002), cautioning that automaticity may be expected only for perceptual and cognitive mechanisms under heavy time pressure. In principle, if very fast, capacity-free processing was not required to solve some information-processing problem under ancestral

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conditions, then there would have been no selection for automaticity in that psychological adaptation. In practice, though, some psychological adaptations seem to fire unavoidably, seem to run very fast and seem rather robust against interference from other tasks (e.g., see Öhman & Mineka 2001 for a discussion of the *fear module*). The automaticity debate has continued largely at the theoretical level, with little input from empirical research on whether specific psychological adaptations actually can operate automatically, that is, without interference from other concurrent tasks.

The aim of this study is to contribute to filling that empirical gap. We test whether the automaticity criterion accurately describes facial attractiveness perception using the psychological refractory period (PRP) paradigm that has been used in hundreds of cognitive psychology experiments (for reviews, see Lien & Proctor, 2002; Lien, Ruthruff, & Johnson, 2006; Marois & Ivanoff, 2005) but has not been widely used to test evolutionary hypotheses. Our goal here is not to test whether facial attractiveness perception is an adaptation—research review below puts that beyond reasonable doubt. Rather, our goal is to test whether automaticity is a useful criterion for identifying psychological adaptations.

Perception of facial attractiveness fits many of the criteria that have been proposed for identifying species-typical, psychological adaptations (Fink & Penton-Voak, 2002; Gallup & Frederick, 2010; Perrett, 2010; Rhodes & Zebrowitz, 2002; Rhodes, 2006). It emerges early in infant development (Geldart, Maurer, & Carney, 1999; Rubenstein et al., 1999; Slater, Quinn, Hayes, & Brown, 2000; Van Duuren, Kendell-Scott, & Stark, 2003). It shows many similarities across cultures (Cunningham, Roberts, Barbee, Druen, & Wu, 1995; Langlois et al., 2000; Rhodes, Lee et al., 2005; Rhodes, Yoshikawa, et al., 2001). Its early stages can occur preattentively (Palermo & Rhodes, 2007) in specialized brain areas, such as the fusiform face area and lateral occipital cortex (Chatterjee, Thomas, Smith, & Aguirre, 2009) and right orbitofrontal cortex (Tsukiura & Cabeza, 2011). It focuses on facial cues thought to reveal underlying genetic quality and phenotypic condition (Grammer, Fink, Møller, & Thornhill, 2003; Lie, Rhodes, & Simmons, 2008; Thornhill & Gangestad, 1999), including bilateral symmetry (Jasienska, Lipson, Ellison, Thune, & Ziomkiewicz, 2006; Jones et al., 2001; Koehler, Rhodes, & Simmons, 2002; Rhodes, Zebrowitz et al., 2001), structural averageness (Komori, Kawamura, & Ishihara, 2009a,b; Little & Hancock, 2002; Rhodes, 2006), sexually dimorphic hormone markers (DeBruine et al., 2006; Johnston, Hagel, Franklin, Fink, & Grammer, 2001; Law-Smith et al., 2006; Little, Jones, DeBruine, & Feinberg, 2008; Thornhill & Gangestad, 2006), and quality of skin and lip coloration (Matts, Fink, Grammer, & Burquest, 2007; Stephen & McKeegan, 2009). Some aspects of female perception of male facial attractiveness show adaptive shifts across the ovulatory cycle (Anderson et al., 2010; Jones et al., 2008). Face attractiveness perception is also sensitive to cues of self-resemblance (DeBruine, Jones, Little, & Perrett, 2008) and cues of youthfulness (Gunn et al., 2009).

Given its impressive credentials as an adaptation, we might expect facial attractiveness perception to fit the classic Fodor (1983) mandatoriness/automaticity criterion. Mandatoriness means that once a relevant (domain specific) stimulus is presented, the modular process should start without any voluntary intention and should proceed without conscious awareness or control. This mandatoriness is often referred to as automaticity (Barrett & Kurzban, 2006), but automaticity can mean a few different things (Bargh, 1994; Palermo & Rhodes, 2007). For example, automaticity can mean processing of a stimulus without focused attention or conscious awareness (Bargh, 1997). Automaticity can also mean that a process is rapid (Palermo & Rhodes, 2007). Finally, automaticity can mean a process that requires little or no attentional resources, so it would not interfere with other tasks that require attentional resources (Schneider & Chein, 2003). Below, we will address several different meanings of automaticity with respect to facial attractiveness perception and then describe the specific concept of automaticity we are going to test in the current study.

1.1. The automaticity of facial attractiveness perception

To investigate whether a target stimulus can be processed without a participant's focused attention or conscious awareness, many studies use brief target presentation with forward and/or backward masks. Olson and Marshuetz (2005) showed that participants could unconsciously perceive the attractiveness level of a face presented for only 13 ms with forward and backward masks. Based on a study using a similar experimental setting with a target face presentation time of 100 ms, Locher, Unger, Sociedade, and Whal (1993, p. 741) concluded that "perception of differential attractiveness occurs effortlessly or automatically with the initial encoding of sensory data." Electrophysiological studies have also provided evidence of very rapid facial attractiveness perception, suggestive of automaticity. Werheid, Schacht, and Sommer (2007) observed that, while their participants were performing facial attractiveness judgments, attractive faces induced an early posterior negativity (EPN) between 230 and 280 ms after target onset, indicating fast appraisal of facial attractiveness. In another study, Schacht, Werheid, and Sommer (2008) also observed early event-related brain potentials (~150 ms after stimulus onset) from attractive and unattractive faces compared with intermediate faces. Hooff, Crawford, and Vugt (2010) further reported that task-unrelated attractive or unattractive opposite-sex faces induced large P2 amplitudes (observed in a similar time window as the EPN: 150–250 ms), suggesting a fast attentional bias toward attractive or unattractive faces rather than intermediate level faces.

The studies mentioned above support the notion that facial attractiveness perception is automatic in the sense of being effortless, unconscious, and rapid. However, it remains an open question whether facial attractiveness perception is automatic in the sense of being capacity-free or not requiring any central attentional resources, such that it does not suffer interference from other tasks that need the central attentional resources (Schneider & Chein, 2003). In this article, we investigate whether facial attractiveness perception is automatic in this capacity-free sense. Capacity-free can also be understood as *processing independence*: a certain process operates independently of other ongoing processes, such that its speed, accuracy, and other operating parameters are not affected by those other processes. Note, however, that processing independence does not mean that the task requires no information processing at all, only that its processing is independent of the central attentional resources that are required for other tasks. Much of the interference between cognitive tasks arises from competition for the same central attentional resources, so a task that shows processing independence is typically construed as "capacity-free"—requiring no central attentional resources. This concept of automaticity as processing independence should be distinguished from automaticity as mandatoriness—which means that a process is involuntarily initiated by a certain domain-specific stimulus. Processing independence and mandatoriness are logically independent—a process could be mandatory yet require capacity, or capacity-free yet not mandatory. Throughout this article, we focus on automaticity in the sense of processing-independent or capacity-free, rather than mandatoriness.

To test whether facial attractiveness perception is automatic in this capacity-free sense, we used the PRP paradigm described next, which offers a well-established means of assessing capacity-free automaticity.

1.2. The PRP paradigm

In the PRP paradigm, participants make speeded responses during two concurrent tasks, Task 1 and Task 2. Each task typically includes exposure to some kind of stimulus (such as a face photo displayed on a monitor), a simple decision about the stimulus (such as whether it is attractive or unattractive), and a fast forced-choice response (such as a tapping one of two keys on a keyboard). The crucial independent variable is the time interval between the onset of the Task 1 stimulus and the onset of the Task 2 stimulus, known as the *stimulus-onset asynchrony* (SOA). At relatively long SOAs (e.g., 900 ms), the simple tasks can often be performed independently, with no competition for attentional resources, because participants complete Task 1 before the Task 2 stimulus appears. This long-SOA condition provides baseline performance levels for the two tasks. The question, then, is how much slower the Task 2 responses become at short SOAs (e.g., 100 ms), when the two stimuli are presented at almost the same time, such that Task 1 processing is still occurring when the Task 2 stimulus appears. PRP experiments typically show substantial slowing of Task 2 responses at short SOAs, a phenomenon known as the *PRP effect* (see Lien & Proctor, 2002, for a review).

A dominant explanation for the PRP effect is the *central bottleneck model*. This model's core assumption is that central processes (e.g., decision making and response selection) occur for only one task a time, as illustrated in Fig. 1. At short SOAs, this limitation creates a processing bottleneck whereby Task 2 central processes must wait for Task 1 central processes to finish, delaying Task 2 response/reaction time (RT). The amount of response delay imposed by the central bottleneck, which is also called "cognitive slack" (illustrated by the dotted lines in Fig. 1), is equivalent to the PRP effect.

Within the framework of the central bottleneck model, "locus-of-slack" logic is used to determine whether a target mental process (e.g., the attractiveness perception) in Task 2 is "automatic" in the sense of being processing-independent or capacity-free. This logic requires that we manipulate the difficulty level (easy vs. difficult) of the target mental process in Task 2. If the target process *is* automatic, meaning

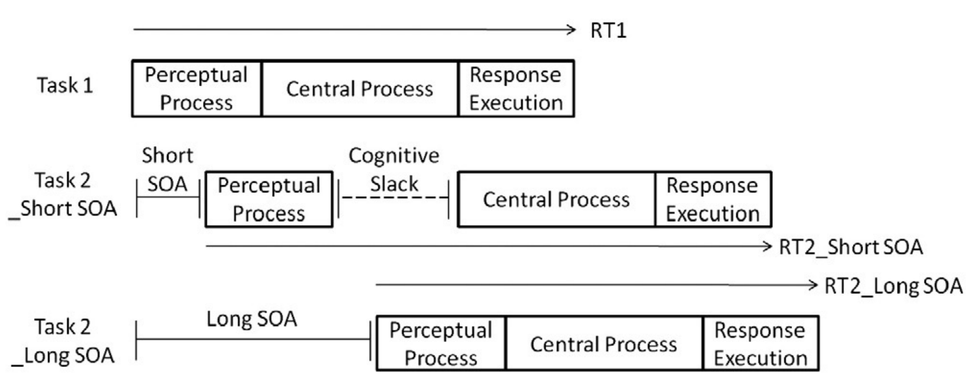

Fig. 1. Illustration of the central bottleneck model and how it produces a PRP effect (substantial slowing of Task 2 responses at short SOAs). The key assumption of this model is that central process occurs for only one task a time; that is, Task 2 central process cannot operate until Task 1 central process is finished. At short SOAs, this limitation causes a period of cognitive slack in Task 2, indicated by the dotted lines in the middle. This waiting period produces a corresponding increase in Task 2 RT at short SOAs but not long SOAs. RT1 is Task 1 RT, and RT2 is Task 2 RT.

that it can occur in parallel with Task 1 central processes, then any lengthening of the target process due to increased difficulty can be absorbed into the cognitive slack (for more details, see Pashler 1994 and Schweickert 1978). The result is a markedly decreased difficulty effect of Task 2 at short SOAs relative to long SOAs (see Fig. 2A). However, if the target process is *not* automatic, so that it cannot occur in parallel with Task 1 central processes, then the difficulty effects should be additive with SOA (i.e., lengthening the target process will produce a corresponding lengthening in overall Task 2 RT across all the SOAs; see Fig. 2B).

To test whether perception of facial attractiveness is automatic in this capacity-free sense, we conducted two studies using the PRP paradigm. In each study, Task 1 required judging whether a tone was high or low in pitch, and Task 2 required judging whether a face was attractive or unattractive.

2. Experiment 1

2.1. Methods

2.1.1. Participants

Fifty-five female undergraduate students from the University of New Mexico participated in exchange for course credit. They ranged in age from 18 to 27 years, with a mean age of 19.4 years. After exclusion criteria noted below, 36 participants gave useful data.

2.1.2. Apparatus and stimuli

For the tone-discrimination task (Task 1), one of two tones (1.0 or 1.5 kHz) was presented through headphones. For the facial attractiveness judgment (Task 2), pictures of male university students' faces were presented on 19-in. high-resolution color monitors. The photographed students had previously consented to allow their pictures be used in studies of attractiveness. All pictures were taken under the same lighting conditions, distances, backgrounds, and framing (including hair and the top of the shoulders). At a typical viewing distance of 50 cm, the face area was about 12°×12° measured from cheek to cheek and from the middle of the forehead to the bottom of the chin.

The original picture pool consisted of 49 male faces. Based on ratings of attractiveness in a pilot study (not shown here), we selected six pictures for each of the following four attractiveness levels: very attractive, somewhat attractive, somewhat unattractive, and very unattractive. The stimuli for the *easy condition* consisted of very attractive and very unattractive faces, whereas the stimuli for the *difficult condition* consisted of somewhat attractive and somewhat

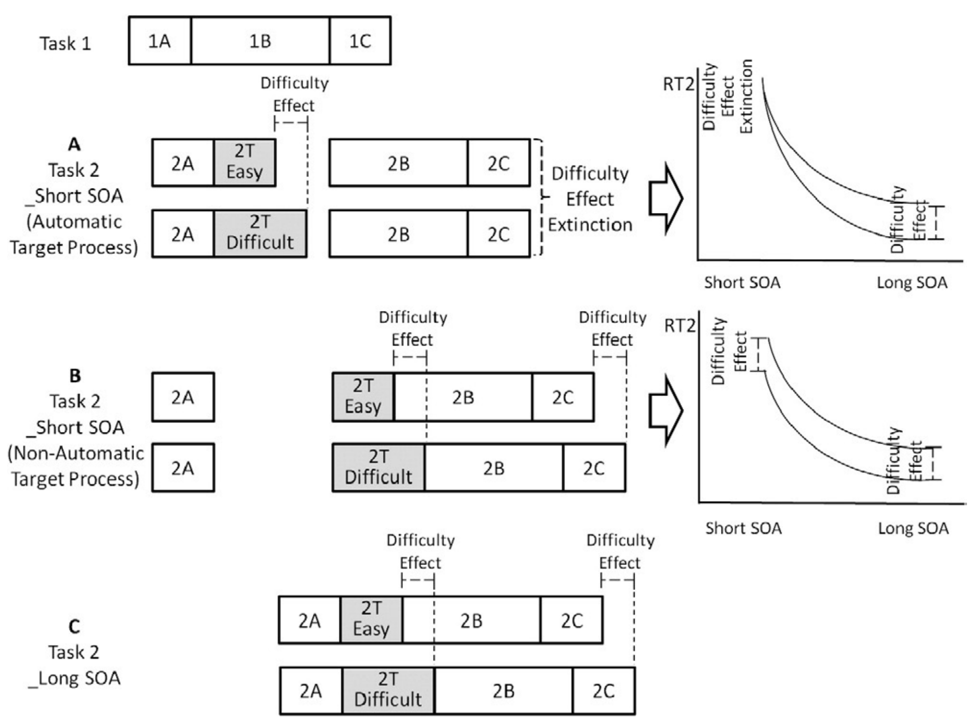

Fig. 2. (A) Predictions regarding the difficulty effect at short SOAs if the target process in Task 2 (2T) does not require central attentional resources (automatic). In this case, the difficulty effect is absorbed into the cognitive slack created by postponing the Task 2 central process (2B) until Task 1 central process (1B) is finished. As a result, the difficulty effect on Task 2 RT (RT2) would markedly decrease at short SOAs. (B) A scenario showing what would happen if the target process does require central attentional resources (i.e., nonautomatic). In this case, the target process can occur only after 1B is finished. As a result, any lengthening of the target process will increase overall RT2 at short SOAs. (C) The difficulty effect would be fully reflected in RT2 at long SOAs, regardless of the automaticity of the target process. 1A, 1B, and 1C are the perceptual process, central process, and response execution process of Task 1, respectively. 2A, 2B, and 2C are the corresponding processes of Task 2. 2T is the target process (facial attractiveness perception) in Task 2.

unattractive faces. The easy and difficult trials were mixed together randomly within blocks.

2.1.3. Procedure

At the beginning of each trial, a cross-shaped fixation point (black) was presented on a white background for 1000 ms. After the fixation point disappeared, the Task 1 stimulus, either a low-pitched or high-pitched tone, was presented for 200 ms. Participants were asked to indicate quickly whether the tone was low or high in pitch by pressing either the horizontally adjacent "C" or "X" keys, respectively, on the keyboard using their left middle or index finger. After one of four different SOAs (100, 300, 500, 900 ms), the Task 2 stimulus, the male face, was presented on the screen for maximum of 3000 ms, or until a response was registered. Participants were asked to judge whether the face was attractive or unattractive as quickly as possible. Half of the participants pressed the two horizontally adjacent "B" and "N" keys for attractive and unattractive faces, respectively, using their right index or middle finger; the other half used the reverse key assignment.

After each trial, participants received a feedback message regarding both tasks. Task 1 feedback was presented on the left side of the screen and Task 2 feedback on the right side, simultaneously for 1000 ms. If the Task 1 response was correct, RT for that task in milliseconds (RT1) was presented in blue letters. For incorrect or slow (longer than 1500 ms) Task 1 responses, a "Wrong" or "Too slow" error message was presented in red letters. Because Task 2 was a subjective judgment, only the RT for that task (RT2) was presented as feedback, in blue letters. If RT2 was longer than 3000 ms, a "Too slow" message was presented in red letters. In addition to this trial-by-trial feedback, participants also received feedback after each block of 32 trials regarding their overall performance during that block. If Task 1 accuracy was less than 90% during that block, a feedback message encouraging more accurate responding was presented. For Task 2, if participants responded "attractive" on less than 33% of trials, they were encouraged to use both response keys about equally often.

Before the main experimental blocks, all participants completed two practice blocks to help them learn the two component tasks. In the first practice block (48 trials, two pitch tones for each of the 24 face stimuli), participants were asked to do Task 1 only, making the high-or-low tone discrimination, ignoring the face stimulus. In the second practice block (24 trials, 1 trial for each face stimulus), participants were asked to do Task 2 only, making the attractive-or-unattractive face judgment, ignoring the tone. The instructions emphasized that all the face pictures were from normal university students, not celebrities or models. Also, participants were encouraged to set their response criterion such that they would use the attractive and unattractive responses equally often. If participants responded "attractive" on less than 33% of trials in the first Task 2-only practice block, they were asked to perform another Task 2-only practice block. No participant performed more than three Task 2-only practice blocks. Each participant then performed 12 main experimental blocks of 32 trials each. Participants were encouraged to rest between blocks. Including the practice blocks, the whole experiment typically lasted about 40 minutes.

2.1.4. Design

During the experimental blocks, all combination of the four different SOAs (100, 300, 500, 900 ms) and the two Task 1 stimuli (high or low tone) were selected twice each (4∗2∗2) for each of the 24 face pictures, yielding 16∗24 or 384 trials in total for each participant. All the trials were randomly distributed in the main experimental blocks.

2.2. Results for Experiment 1

The first experimental block and the first trial of each subsequent block, regarded as warm-up trials, were not included in the data analysis. Trials were excluded if RT1 was below 200 ms or above 1500 ms (2% of all trials) or if RT2 was below 200 ms or above 2500 ms (5% of all trials). Trials with incorrect responses to Task 1 were also discarded from RT analyses (3% of all trials). We removed data from one participant with low Task 1 accuracy (below our criterion of 85%). We also removed data from 6 participants who showed evidence of "grouping" their responses (i.e., their long-SOA RT1 was more than 100 ms longer than their short-SOA RT1, suggesting a tendency to withhold their Task 1 response until they had also performed Task 2 at long SOAs—see Ulrich & Miller, 2008). Data from one face picture that had been assigned to the very attractive group were discarded due to an unexpectedly low proportion of "attractive" responses (52%). Finally, we discarded data from 12 participants who showed low Task 2 accuracy (less than 75%) in the easy condition. Although the subjective responses from this minority may be valid with respect to their own criteria, if their classification is different from our classification of the face pictures, then they would not necessarily show the desired difficulty effect. After this data selection process, 36 of 55 participants remained for further data analysis.

2.2.1. RT analysis

Analysis of variance was conducted with an α level of .05. When assumptions of sphericity were violated, p values were adjusted using the Greenhouse–Geisser or Huynh–Feldt correction according to their ε values. The mean RTs and error rates for Task 1 and Task 2 are shown in Table 1. As shown in Fig. 3, the mean RT2 increased as SOA decreased, reflecting dual-task interference [$F(3, 105)=147.24$, $p<.001$, $\eta^2_p=0.81$]. The overall amount of dual-task interference, or PRP effect (mean RT2 increase from the longest SOA to the shortest SOA), was 197 ms. This corresponded to the amount of "cognitive slack" in this dual-task experiment and was available to absorb the following Task 2 difficulty effects. The overall Task 2 difficulty effect (mean RT2 difference between the easy and the difficult

Table 1
Mean RTs (in milliseconds) and mean accuracy (AC) for Task 1 and Task 2 as a function of Task 2 difficulty and SOA (in milliseconds) in Experiment 1 and Experiment 2

	SOA							
	100		300		500		900	
Task 2 difficulty	RT	AC	RT	AC	RT	AC	RT	AC
Experiment 1								
Task 1								
Difficult	656	0.96	677	0.97	706	0.98	674	0.98
Easy	640	0.96	672	0.97	691	0.98	656	0.98
Task 2								
Difficult	767	NA	649	NA	592	NA	569	NA
Easy	733	NA	619	NA	569	NA	536	NA
Experiment 2								
Task 1								
Difficult	613	0.94	642	0.95	652	0.96	617	0.95
Easy	618	0.93	639	0.95	645	0.96	610	0.96
Task 2								
Difficult	788	NA	692	NA	643	NA	615	NA
Easy	767	NA	653	NA	611	NA	584	NA

NA indicates not applicable.

conditions) was 30 ms [$F(1, 35)$=24.15, p<.001, η^2_p=0.41]; it was 34, 31, 22, and 33 ms at the 100-, 300-, 500-, and 900-ms SOAs, respectively.

If perception of facial attractiveness requires some central attentional resources, we should see similar difficulty effects across SOAs. Consistent with this prediction, the interaction between Task 2 difficulty and SOA was not significant [$F(3, 105)$=0.56, p=.64, η^2_p=0.02]. Conversely, the alternative hypothesis that attractiveness perception is fully automatic predicts complete absorption of the modest Task 2 difficulty effect (mean, 30 ms) into the long period of cognitive slack (mean, 197 ms) at the shortest SOA. Contrary to this prediction, the difficulty effect of 34 ms [95% confidence intervals (CIs), 15–53] at the shortest SOA was significantly greater than 0 ms [$F(1, 35)$=13.09, p=.001, η^2_p=0.27], and it was not different from the 33-ms difficulty effect at the longest SOA [$F(1, 35)$=0.003, p=.96, η^2_p=.001]. These findings show that perception of facial attractiveness does require some central attentional resources and is therefore not fully automatic.

3. Experiment 2

In Experiment 1, we assigned two horizontally adjacent ("B" and "N") keys to the attractive or unattractive responses. Although arbitrary key assignments are frequently used in cognitive psychology experiments, the task would be even easier with a higher level of stimulus–response compatibility (SRC). Chen and Bargh (1999) have shown that participants respond to positively valenced stimuli faster when using an *approach response* (e.g., pushing a lever toward the stimulus) rather than an *avoid response* (e.g., pulling a lever away from the stimulus). Conversely, participants respond to negatively valenced stimuli faster when using an avoid response rather than an approach response. Therefore, to better facilitate the use of any automatic attractiveness perception tendencies and to exploit such SRC effects, we used a more natural response key assignment in Experiment 2, assigning the "U" key (closer to the screen) for "attractive" judgments and the "N" key (farther from the screen) for "unattractive" judgments.

3.1. Methods

3.1.1. Participants

One hundred three female undergraduate students from the University of New Mexico participated in exchange for course credit. They ranged in age from 18 to 25 years, with a mean age of 19.4 years. After applying the exclusion criteria noted below, 73 participants gave useful data.

3.1.2. Apparatus, stimuli, procedure, and design

Experiment 2 was similar to Experiment 1, except that one picture in the very attractive condition in Experiment 1

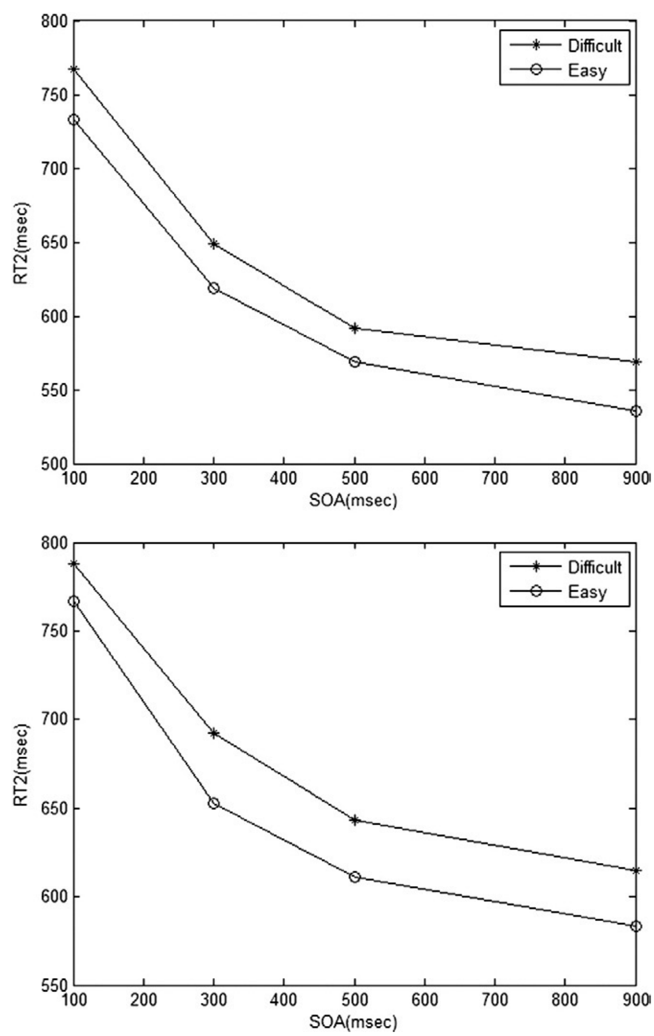

Fig. 3. Mean RT (in milliseconds) for Task 2 in Experiment 1 (upper panel) and 2 (lower panel) as a function of SOA (in milliseconds) and Task 2 difficulty.

with a low proportion of "attractive" responses was replaced by a new one. Also, participants pressed the "U" key on the keyboard for attractive pictures and the "N" key for unattractive pictures.

3.2. Results for Experiment 2

Data quality control was similar to that for Experiment 1. The first experimental block and the first trial of each subsequent block, regarded as practice or warm-up trials, were not included in the data analysis. Trials with RT1 below 200 ms or above 1500 ms (2% of all trials) or RT2 below 200 ms or above 2500 ms (2% of all trials) were discarded. Incorrect Task 1 trials were discarded from RT analyses (4% of all trials). Data from two participants with low Task 1 accuracy (below our criterion of 85%) and five participants with unusually long RT1 (greater than 900 ms) were discarded. We also removed data from six participants who showed evidence of grouping responses. Finally, we discarded data from 17 participants who showed less than 75% agreement with our classification of the very attractive and very unattractive faces. After these exclusion criteria, 73 participants remained for further data analysis.

3.2.1. RT analysis

The mean RTs and error rates for Task 1 and Task 2 are shown in Table 1. As shown in Fig. 3, the mean RT2 increased as SOA decreased [$F(3, 216)=231.47$, $p<.001$, $\eta^2_p=0.76$], showing an overall dual-task interference, or PRP effect, of 178 ms. The overall Task 2 difficulty effect was 31 ms [$F(1, 72)=53.92$, $p<.001$, $\eta^2_p=0.43$]; it was 21, 40, 32, and 31 ms at the 100-, 300-, 500-, and 900-ms SOAs, respectively.

The interaction between Task 2 difficulty and SOA was not significant [$F(3, 216)=2.27$, $p=.90$, $\eta^2_p=0.03$]. That is, the difficulty effects were roughly constant across the four SOAs, again showing that perception of facial attractiveness requires some central attentional resources. The difficulty effect of 21 ms (95% CIs, 6-36) at the shortest SOA was again significantly greater than 0 ms [$F(1, 72)=7.84$, $p=.007$, $\eta^2_p=0.10$] and was not significantly different from the 31-ms difficulty effect at the longest SOA [$F(1, 72)=1.46$, $p=.231$, $\eta^2_p=0.02$].

Experiment 2 used a more "natural" key assignment than Experiment 1, allowing participants to "approach" the attractive faces by pressing the "U" key closer to the screen and to "avoid" the unattractive faces" by pressing the "N" key farther from the screen. Despite trying to take advantage of any SRC effects, we still found evidence that perception of facial attractiveness is not fully automatic in the sense of being capacity-free.

4. Discussion

In two experiments ($N=36$ and $N=73$ participants after data quality control; 384 trials per participant), we found consistent evidence that female participants could not discriminate levels of male facial attractiveness while their central attentional resources were occupied by a tone-discrimination task. The estimated amounts of cognitive slack (i.e., the PRP effects) were similar across experiments, at 197 ms in Experiment 1 and 178 ms in Experiment 2. The mean difficulty effects were similar at 30 and 31 ms in Experiments 1 and 2, respectively. If attractiveness perception are fully automatic, then the difficulty effects should have disappeared at short SOAs, or at least been markedly reduced; contrary to this prediction, the difficulty effects showed no noticeable or significant drop at short SOAs in either experiment. In both experiments, the difficulty effects were roughly constant across the four SOAs of 100, 300, 500, and 900 ms (Experiment 1: 34, 31, 22, and 33 ms; Experiment 2: 21, 40, 32, and 31 ms). Given the locus-of-slack logic illustrated in Figs. 1 and 2, these results indicate that perception of facial attractiveness is not fully automatic in the sense of being capacity-free.

How can we infer anything about natural face perception from such an artificial pair of tasks? It is crucial to understand what the locus-of-slack logic in dual-task PRP experiments does and does not imply about the mental processes used in Task 2. In these studies, there were at least two distinct mental processes in Task 2: facial attractiveness perception, which could be capacity-free or not, and the response key selection (the Task 2 central process), which definitely needs central attentional resources. The PRP paradigm does not require that the response to Task 2 be ecologically valid, adaptively relevant or evolutionarily representative. We acknowledge that making a binary forced-choice button press about whether a face is attractive may not be an evolutionarily natural central process, and it definitely requires some attentional resources. However, having such an unnatural and attentional-resource consuming process in Task 2 was exactly what was required to create the cognitive slack at short SOAs (see the dotted lines in Fig. 1). If a Task 2 central process requires some attentional resources, it can create cognitive slack at short SOAs due to the competition with Task 1 central processes, which also needs the same resources. Therefore, it does not matter whether the Task 2 central process is a forced-choice button press or some other response, as long as it requires central attentional resources and can create cognitive slack at short SOAs. In this case, we wanted to determine whether facial attractiveness perception with different levels of difficulty can occur automatically during the cognitive slack, which, inturn, would reduce or eliminate the difficulty effects at the short SOAs. What matters is the ecological validity of the attractiveness perception and the corresponding difficulty manipulation, not the ecological validity of the Task 2 central process or the Task 2 response execution. Our findings show that the extra time needed for attractiveness judgments when faces were near the borderline (i.e., the difficult condition) could not be absorbed into the cognitive slack. Thus, the human mind cannot finish the perceptual process of encoding facial attractiveness level (attractive vs.

unattractive) without using central attentional resources. It is precisely by using such an artificial task, with the pressures for high speed, high accuracy, and two novel tasks at once, that we can examine the natural process of perceiving facial attractiveness.

These results are consistent with previous studies showing that processing other types of facial information, such as a person's identity, requires attentional resources (Bindemann, Burton, & Jenkins, 2005; Palermo & Rhodes, 2002; Raymond, Shapiro, & Arnell, 1992; but see also Boutet, Gentes-Hawn, & Chaudhuri, 2002). Perceiving facial expression of emotions also seems to require attentional resources, although study results are more mixed (Anderson, 2005; Shaw, Lien, Ruthruff, & Allen, in press; Tomasik, Ruthruff, Allen, & Lien, 2009; for a review see Palermo and Rhodes, 2007).

Although our findings suggest that perception of facial attractiveness is not fully automatic, they do not rule out the possibility that much of facial attractiveness perception can occur very rapidly in early stages of visual processing (Hooff, Crawford, & Vugt, 2010; Schacht et al., 2008; Werheid, Schacht, & Sommer, 2007), even with limited amounts of visual information (Locher et al., 1993) and without conscious awareness of the facial stimulus (Olson & Marshuetz, 2005). As Bargh (1994) suggested, a perceptual process might be automatic in some senses, such as fast, robust, and unconscious, and can be mandatory, without being automatic in other senses, for example, capacity-free in the PRP paradigm. Similarly, Compton (2003) suggested that salient emotional stimuli such as faces can be processed "automatically" in two different senses: in a preattentive way (which might be capacity-free) or in an attentionally privileged way (which might not be strictly capacity-free but receiving priority when attention is allocated spontaneously to different stimuli). Our demanding dual-task paradigm may force participants to allocate their attention in rather unnatural and exhausting ways. This is useful in testing whether a task can be performed in a preattentive, capacity-free way, but it is not designed to test whether a task is attentionally privileged under natural conditions. We suspect that, outside the laboratory, young women exposed to tones of various pitches and to male faces of various attractiveness levels will find their attentional resources drawn very strongly to the latter (see Maner, Gailliot, Rouby, & Miller, 2007), such that perception of facial attractiveness feels fully "automatic" for all intents and purposes.

Furthermore, our findings do not imply that all constituent parts of facial attractiveness perception require attentional resources. It remains possible that some attractiveness cues (e.g., averageness of particular features or quality of hormone markers such as brow ridges, cheek bones or beards) might be processed fully automatically, with attentional resources required only when integrating these cues with other configural information (e.g., bilateral symmetry) into an overall judgment (see Amishav and Kimchi, 2010).

Our results need to be considered in their chronometric and adaptive context. Average RTs to make judgments of facial attractiveness were consistently less than 650 ms at the longest SOA (900 ms), and difficult attractiveness judgments took only about 30 ms longer than easy judgments. It is hard to imagine ancestral conditions under which attractiveness judgments would need to be made more quickly than this. A good case can be made that selection favored very fast detection of fear expressions on the faces of others (e.g. Palermo & Rhodes, 2007), so one can avoid whatever predator or attacker is inciting the fear. By contrast, given that human mate choice and courtship typically require at least a few hours, with a large investment of conscious, attentive, thoughtful interaction (Geher & Miller, 2007; Miller, 2000), a speed advantage of a few hundred milliseconds in judging facial attractiveness seems trivial. This point raises a problem with "automaticity" as a generic criterion for adaptedness: if a perceptual decision already happens in less than a second with barely noticeable demands on attention and feeds into a process of social or sexual interaction that lasts for at least a few minutes, as most significant interactions with conspecifics do, then there may be no fitness benefits of pushing the perceptual process to be even faster or less attention demanding than it already is. Barrett et al. (2006) made a similar argument against automaticity for more leisurely social and sexual judgment tasks.

This study has several limitations that should be addressed in further research. The participants were all young adult female university students in the United States, with about half being Anglo (white/Caucasian) and half being Hispanic (with various levels of genetic admixture from European and Native American populations). Results might differ for participants of different ages and sexes, or, less plausibly, for participants of different nationalities and ethnicities. Older adult females with more social experience might perhaps acquire higher automaticity in judging male attractiveness. Women at peak fertility, just before ovulation, might show higher automaticity in responding to highly attractive male faces, given their higher incentives for poaching good genes. Males might show higher automaticity in judging female facial attractiveness, given their higher incentives for opportunistic short-term mating. The face photos were from male university students reflecting a normal range of attractiveness; it is possible that extremely attractive or extremely repulsive faces are processed through different, capacity-free channels (e.g., see Ackerman et al., 2009).

This is the first evolutionary psychology study to use the PRP paradigm to investigate whether attractiveness perception is "automatic" in the sense of requiring no central attentional resources. We found that even the perception of facial attractiveness—a premier example of an adaptation, a very well-studied set of mechanisms at the heart of human mate choice and a process central to reproductive success—is not automatic in the sense of requiring no central attentional resources. Based on the lack of automaticity in that process, we could conclude that facial attractiveness perception is not an adaptation, just as DeSteno et al. (2002) concluded that the sex difference in jealousy judgment is not an adaptation. However, given the vast evidence suggesting that attractiveness perception reflects psychological adaptation, we instead suggest that this finding provides further evidence that automaticity is a poor guide to adaptedness, in accord with theoretical arguments made by other evolutionary psychologists (e.g., Barrett et al., 2006; Barrett & Kurzban, 2006; Pinker, 1997; Sperber, 2005). Perceptual adaptations will evolve capacity-free automaticity only when there are selection pressures to do so (Barret et al., 2006). For many social and sexual decisions that happen over the course of hours (for short-term mate choice) to months (for long-term mate choice), those selection pressures were simply not there, and there was plenty of time to use central attentional resources to appreciate the beauty of others.

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