

SHORT AND SWEET

Long-term adaptation effects of highly familiar faces are modulated by adaptation duration

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Abstract. Adaptation to manipulated versions of face images can induce strong adaptation effects in face perception and the adjustment of memory representations has been suggested to underlie this effect. In previous studies such effects have been observed after short as well as long delays between adaptation and test (5 min and 24 h) and they were evident in face images identical to the adapting stimuli as well as in new images of the same individual and in faces that were not shown during adaptation (factor transferability). By using regression analysis, here we show that adaptation duration modulates the size of the adaptation effect, which was evident after both short and long time delays and across all levels of transferability tested.

The term adaptation refers to the ability to adjust to new information and experiences. The ability to adapt is essential to live and survive in an ever-changing environment such as the humans' ecosystem. Visual adaptation, in particular, is defined as the process by which the visual system alters its function in response to misfits between the mental representation and the perceived object (eg Clifford et al 2000). Visual adaptation has been shown in action for single-feature dimensions including size (Köhler and Wallach 1944), orientation (Gibson 1933), colour (eg Webster and Mollon 1991), and motion (eg Motoyoshi et al 2007; Wohlgenuth 1911) and is also demonstrable for more complex stimuli such as faces (eg Webster and MacLin 1999), cars (eg Carbon 2010), and scenes (Zhang et al 2009). In the face-distortion aftereffect, an original face appears slightly distorted when perceived after a period of adaptation to a spatially strongly distorted version of the face (Webster and MacLin 1999). Similar aftereffects have been found in other feature dimensions of faces such as age (Elliott et al 2011), gender (Webster et al 2004), and identity (Leopold et al 2001).

Adaptation effects vary strongly with respect to their duration. While most studies so far have focused on short-term effects (eg Webster and MacLin 1999), long-term adaptation effects in simple scenes (eg Vidnyánszky and Sohn 2005), and particularly in faces, are still relatively new (up to 24 h, Carbon et al 2007; up to 7 days, Carbon and Ditye 2011). Carbon et al (2007) provided evidence for long-term adaptation effects for highly familiar faces. In this study, participants initially inspected configurally manipulated versions of faces of famous persons. As illustrated in figure 1a, the adapting stimuli had either decreased eye–mouth distances, original eye–mouth distances, or increased eye–mouth distances varied between groups. In the subsequent test phase participants were asked to select the veridical version out of a series of gradually altered versions (figure 1b), and results showed a bias in participants' selections in a direction similar to the respective manipulations (figure 2). This adaptation effect was demonstrated for delays of 5 min (experiment 1) and 24 h (experiment 2) between adaptation and test phase. Moreover, the inspection of a specific image version of a famous person not only changed the veridicality decision of the same image (*pictorial level*), but also transferred to other images of this person (*structural level*) and to images of other persons (*novel level*). Thus, this adaptation

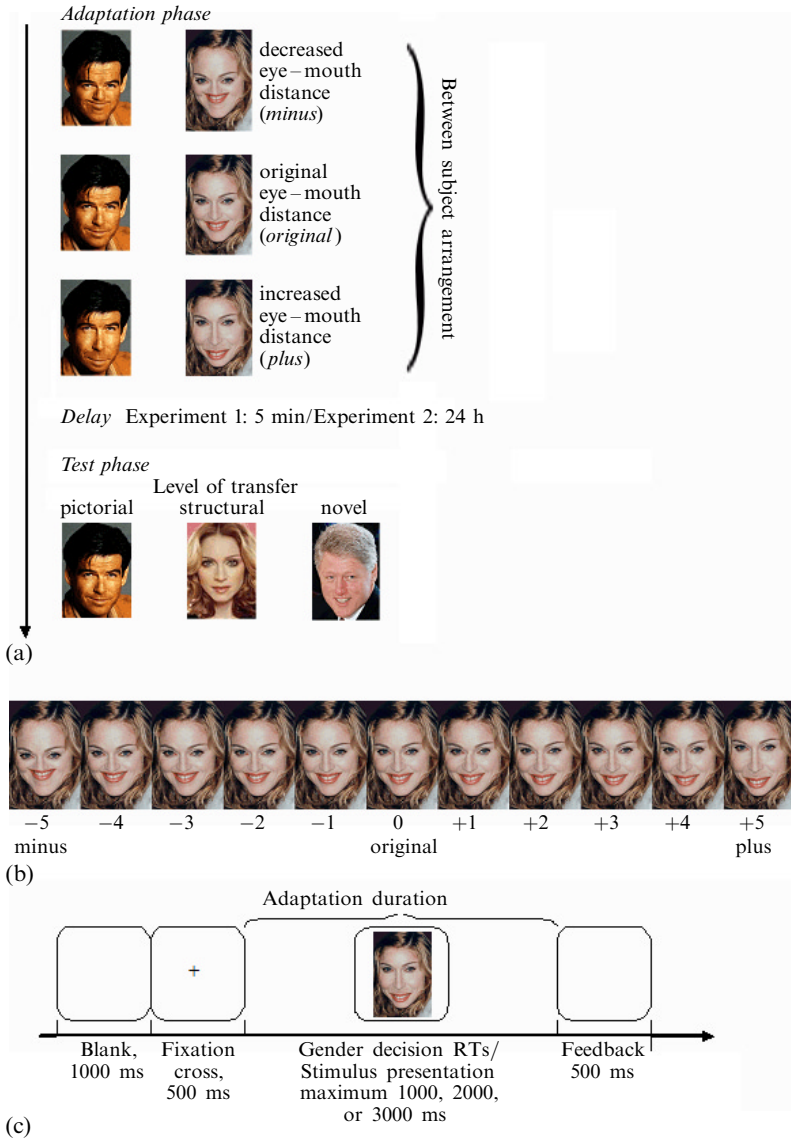


Figure 1. [In colour online, see <http://dx.doi.org/10.1068/p6986>] Experimental design in Carbon et al (2007). (a) General procedure in experiments 1 and 2 including adaptation phase, delay, and test phase. During the adaptation phase, participants either inspected faces with decreased eye–mouth distances (minus), original eye–mouth distance (original), or increased eye–mouth distances (plus) in a between-subject arrangement. Following, there was a delay of either 5 min (experiment 1) or 24 h (experiment 2). In the final test phase, participants performed a veridicality decision on a series of gradually altered face versions. These decisions were performed on face image versions identical to the face image version inspected in the adaptation phase (pictorial level), on face image versions different to the face image version inspected during the adaptation phase, but of the same famous person (structural level), and on face image versions of persons not shown during the adaptation phase (novel level). (b) The original picture of Madonna (central) plus gradually altered face versions presented during the veridicality decision task in the test phases: reduced eye–mouth distances (–1 to –5) and five versions with gradually increased eye–mouth distances (+1 to +5). (c) Trial structure during adaptation phase. After a blank screen of 1000 ms, a fixation cross appeared for 500 ms. Following the adapting face (eg Madonna’s face including decreased eye–mouth distance) was presented until participants gave a response on the gender decision task. Alternatively, the adapting face disappeared after 1000, 2000, or 3000 ms when no response was executed.

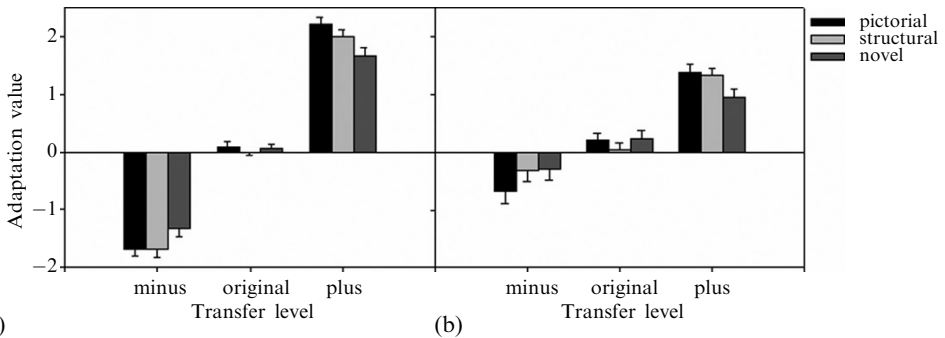


Figure 2. Adaptation values after inspecting configurally manipulated face versions in (a) experiment 1 (including a 5 min delay between adaptation and test phase) and (b) experiment 2 (including a 24 h delay between adaptation and test phase). Participants either inspected faces with decreased eye–mouth distances (minus), original faces (original), or faces with increased eye–mouth distances (plus). The size of adaptation is illustrated for tests on the pictorial (same image of the same person in the adaptation and test phase), structural (different image of the same person in the adaptation and test phase), and novel level (faces presented in the test phase but not in the adaptation phase).

effect appears to have a structural rather than a merely pictorial basis that seems to change the face representation.

While this research demonstrates the longevity and transferability of face adaptation effects it is still an open question how adaptation duration affects the size of the adaptation effect. In two studies, face images were presented for different durations and adaptation effects on the same face image and different images of the same person were assessed (Leopold et al 2005; Rhodes et al 2007). These studies showed a significant impact of the duration of face adaptation on the size of adaptation effects. There were, however, no or very short time delays between adaptation and test phases and thus it is likely that adaptation effects were investigated at the perceptual level. In contrast, Carbon et al (2007) introduced delays of 5 min to 24 h between these phases allowing us to investigate the effects of adaptation duration on the adaptation of memory face representations. In addition to the theoretical implications of this analysis on the adaptability of face representations, there is also a methodological component to the understanding of adaptation duration effects that would be beneficial to our research on higher-level adaptation effects and help to improve the experimental designs of future experiments.

In this study, we analysed the impact of the adaptation duration during the adaptation phase of experiments 1 and 2 in Carbon et al's (2007) study on adaptation effects for highly familiar faces. The experiments allowed us to analyse the effect of adaptation duration on two time levels, ie 5 min and 24 h. Further, we suggest that the effects tested were based on higher-level perceptual mechanisms. The duration of the aftereffects was quite long (up to 24 h) and participants were not required to fixate during adaptation (ie they could scan the complete adapting face stimuli); the latter characteristic particularly excludes pure retinotopic adaptation. Also, besides the adaptation effects found for the initially presented faces, they also transferred to other faces of the same person and to completely novel faces that were not shown during adaptation. On these grounds we conclude that the reported effects are the result of neural mechanisms in higher-level visual areas.

Importantly, these results rule out simpler alternative hypotheses in the form of demand characteristics. Especially in long-term studies it may seem plausible that the biases in participants' responses are based on demand characteristics of the experiment rather than a fundamental neural process that is coding faces. If this was the case,

one would not expect to find parametric effects of adaptation duration on the size of the effects but a more unspecific distribution in participants' responses.

We analysed the impact of the adaptation duration on the size of adaptation effects by means of regression analysis. This analysis requires several steps of data preprocessing. First, the mean adaptation duration (see also figure 1c) was calculated separately for faces that were tested on the pictorial level (same face images of the same person) and on the structural level (different face images of the same person) during the following test phases. During adaptation, faces were presented until participants categorised the stimuli according to gender, but for a maximum of 1000, 2000, or 3000 ms (adaptation duration). For trials in which participants responded after the offset of the stimulus, the respective maximum duration was used in the analysis. This was the case in 3.4% and 2.3% of the trials in experiments 1 and 2 of Carbon et al (2007), respectively. On all trials, feedback was given by presenting the adapting face for 500 ms right after participants had made their responses. This feedback period of 500 ms was not added to the adaptation duration because feedback stimuli were not essential to conduct the instructed task; therefore, we could not ensure that participants inspected this stimulus.

In order to calculate the adaptation effect twenty-four participants of both experiments were included in the analysis. All participants were part of the experimental conditions and thus adapted to distorted versions of the stimuli. Participants that were adapted to the original faces were excluded. The absolute adaptation effect for each participant was calculated for the pictorial, structural, and novel level separately. That is, both positive and negative adaptation values were coded as positive.

The mean adaptation duration of faces of the pictorial and the structural stimulus set were included as independent variables. The mean adaptation effects on the pictorial, structural, and novel levels served as the dependent variable and were separately introduced into linear regression models; we included no constant into the models because adaptation durations of 0 ms would result in no adaptation effects already on a theoretical basis. These data are illustrated in table 1. There is a significant effect of the duration of adaptation on the size of a following adaptation effect. This effect is present after a short delay between adaptation and test phases of 5 min and is still present after a delay of 24 h and was found on all transfer levels (pictorial, structural, and novel).

Table 1. Data of the linear regression models: r^2 and F (p values < 0.001).

Experiment	Levels of adapting faces	Levels of adaptation effect		
		pictorial	structural	novel
1	pictorial	$r^2 = 0.695$, $F_{1,23} = 52.4$	$r^2 = 0.681$, $F_{1,23} = 49.0$	$r^2 = 0.624$, $F_{1,23} = 38.2$
	structural	$r^2 = 0.712$, $F_{1,23} = 56.8$	$r^2 = 0.705$, $F_{1,23} = 55.0$	$r^2 = 0.630$, $F_{1,23} = 39.1$
2	pictorial	$r^2 = 0.561$, $F_{1,23} = 29.4$	$r^2 = 0.530$, $F_{1,23} = 26.0$	$r^2 = 0.526$, $F_{1,23} = 25.5$
	structural	$r^2 = 0.598$, $F_{1,23} = 34.3$	$r^2 = 0.591$, $F_{1,23} = 33.3$	$r^2 = 0.550$, $F_{1,23} = 28.1$

There was a trend for a reduction of explained variance in the novel adaptation level compared to the pictorial and structural levels. Additionally, explained variance was numerically reduced in experiment 2 (24 h delay) compared to experiment 1 (5 min delay). These trends were, however, not significant.

The data demonstrate a strong impact of the duration of face adaptation on the size of face adaptation effects. This was evident for identical and other face images of the same person as well as for face images of different persons. This indicates that the adaptation duration not only affects the size of the adaptation of specific images, ie results from changes in higher-level neural mechanisms associated with face representation on a more

structural level. Furthermore, the present data strongly suggest a thorough control of presentation times (adaptation duration) in future studies on adaptation effects of face representations.

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