RUNNING HEAD: Automatic Emotional Imitation

Emotional Response Valence Facilitates Automatic Imitation of Visual Speech

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Abstract

This study explored effects of emotional valence on automatic imitation. Observing someone perform an action automatically triggers cognitive and neural mechanisms required to perform this action, a phenomenon known as *automatic imitation*. Automatic imitation is measured using the Stimulus Response Compatibility (SRC) paradigm as a facilitation of response times (RTs) when responding to a prompt (e.g., say *aa*) in the presence of a congruent distracter (a video of someone saying *aa*), compared to responding in the presence of an incongruent distracter (a video of someone saying *oo*). Current models propose that automatic imitation springs from learned associations between sensory and motor action representations and is governed by domain-general executive mechanisms. Studies investigating automatic imitation tend to use neutral stimuli, yet everyday interaction often occurs in emotionally charged circumstances, and it is unclear how emotional valence affects automatic imitation. The current study aimed to determine the independent effects of emotional valence of the prompt and the distracter on automatic imitation of speech. Participants conducted a speech SRC task for visual vowel stimuli. Participants produced a written prompt superimposed over a neutral or emotional (happy or angry) distracter video. The participants produced the prompt in a neutral or an emotional (happy or angry) voice. Automatic imitation was facilitated for emotional prompts compared to neutral prompts, but the emotional valence of the distracter did not affect automatic imitation. The results are interpreted in the context of theories of imitation and cognitive control.

Keywords

Imitation, Speech Production, Emotion, Control

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Humans spontaneously imitate observed actions, including gestures, facial expressions, body posture, and speech (Delvaux & Soquet, 2007; Dimberg, 1982; Goldinger, 1998; LaFrance & Broadbent, 1976; Webb, 1969). This tendency to spontaneously imitate observed actions is thought to result from triggering of action execution mechanisms (Buccino et al., 2004; Fadiga et al., 1998), a phenomenon known as *automatic imitation* (Heyes, 2011). The Associative Sequence Learning model (ASL), proposes that automatic imitation originates from learned associations between an action's sensory and motor representations (Heyes, 2011), i.e., from the experience of having performed and observed an action. Automatic imitation is measured using the Stimulus Response Compatibility (SRC) task (Brass, Wohlschläger, Bekkering, & Prinz, 2000; Kerzel & Bekkering, 2000; Roon & Gafos, 2015). Participants in an SRC task speak a prompt (e.g., *ba*) in the presence of a congruent or incongruent auditory, visual, or audiovisual distracters. Responses are slower for incongruent (*da*) than congruent (*ba*) distracters. For congruent distracters, it is assumed that action observation invokes representations associated with performing the prompted action. In contrast, incongruent distracters result in competition between automatically activated production representations and representations required to produce the prompted response, leading to slower responses. Larger differences between incongruent and congruent responses signal more automatic imitation. Automatic imitation is thought to be controlled by domain-general executive functions and is modulated by working memory requirements (van Leeuwen, van Baaren, Martin, Dijksterhuis, & Bekkering, 2009), general cognitive load (Chong, Cunnington, Williams, & Mattingley, 2009), and attentional processing (Catmur, 2016).

Much of everyday interaction occurs under emotionally charged conditions, but it is unclear whether and how automatic imitation is influenced by emotional valence. Current models, including ASL, do not make explicit predictions about effects of emotional valence on automatic imitation. Emotional valence could affect automatic imitation in two ways: either by *observing* an emotional stimulus, or by *producing* an emotional stimulus. Thus far effects of emotional valence on automatic imitation have not been established, neither for valence of the distracter, or for emotional valence of the prompt. We aimed to explore effects of emotional valence of the distracter and the prompt for automatic imitation of speech.

Emotional valence affects processes linked to automatic imitation, most notably conflict resolution. Using interference tasks related to the SRC task, i.e., Simon, Flanker, or Stroop tasks (Kanske & Kotz, 2010, 2011; Xue et al., 2013; Zinchenko, Kanske, Obermeier, Schröger, & Kotz, 2015), it was shown that conflict resolution for spoken actions is more efficient (implying that automatic imitation is inhibited) for emotional than for neutral distracters. Conflict resolution is a defining feature of cognitive control; it requires the detection and resolving of opposing action tendencies (Kanske, 2012). In a conflict resolution task, participants are presented with a prompt together with distracting information. As in the SRC task, if the distracting information is incongruent, the resulting conflict between goal and distracter needs to be resolved to give a correct response. More efficient conflict resolution implies that participants are able to detect and resolve the conflict more efficiently, leading to smaller interference effects. Conflict resolution and automatic imitation have been suggested to work in tandem: more efficient conflict resolution implies less automatic imitation and vice versa (Cross, Torrisi, Losin, & Iacoboni, 2013). Cross et al. suggest that automatic imitation is governed by an active cognitive control system. Breakdown of

this control system is linked to loss of control of imitative behaviour, as can be observed in some patients with frontal lobe lesions (De Renzi, Cavalleri, & Facchini, 1996; Lhermitte, Pillon, & Serdaru, 1996).

As no study has thus far examined how automatic imitation varies as a result of emotional valence of the distracter, it is not straightforward to estimate how processing an emotional distracter affects automatic imitation relative to a neutral distracter. Past work examined how specific emotional valence (e.g., positive versus negative emotional valence, cf., Rauchbauer, Majdandzi, Hummer, Windischberger, & Lamm, 2015) affects automatic imitation for manual gestures. Note that no study has so far also included a neutral emotional valence condition as a baseline. We based our prediction on studies investigating the effect of emotional valence on conflict resolution. We predict that automatic imitation will decrease for emotional distracters compared to neutral distracters, as more efficient processing of the incongruent distracter may result in smaller interference effects, e.g., by increased suppression of activated representations for incongruent distracters (Cross & Iacoboni, 2014; Proctor & Vu, 2006; Rauchbauer et al., 2015).

Furthermore, the current study explored whether and how emotional valence of the prompt affects automatic imitation. Hart, Green, Casp, & Belger (2010) conducted a (manual) conflict resolution study in which participants were primed by showing them emotional images prior to each trial of a Stroop task. They report that reaction times on the incongruent trials were slower when they were paired with a preceding aversive compared to a neutral image. Hart et al. thus found inhibited conflict resolution for emotional relative to neutral primes. Based on their results, it can be predicted that producing an emotional prompt may reduce the efficiency of conflict resolution, and therefore facilitate, or increase, automatic imitation. Hart et al.'s results support

Pessoa's (2008, 2009) model describing the relationship between cognitive and emotional control systems. This model assumes functionally integrated cognitive and emotional systems, where the engagement of cognitive (executive) systems is dependent upon concurrent emotional information being processed. It specifically predicts differential effects of emotion on cognitive control by considering the emotional valence of the distracting stimulus (stimulus-driven effects) and the observer's mental state (state dependence) separately. Stimulus-driven effects affect executive control (including inhibition) as strengthened sensory representations are prioritized. State dependence affects executive function through mood, anxiety, or motivation. Importantly, emotional state can be manipulated by interfering with participants' facial configurations. For instance, in Niedenthal et al. (2001) participants identified the point in time when a morphed face changed from happy to sad, and vice versa. Participants were slower to perform the task when their facial muscle movements were restricted by keeping a pen sideways in their mouth. Similar effects of restricting or manipulating participants' facial movements on emotion recognition have been reported (Oberman, Winkielman, & Ramachandran, 2007; Ponari, Conson, D'Amico, Grossi, & Trojano, 2012; Wingenbach, Brosnan, Pfaltz, Plichta, & Ashwin, 2018). Based on Pessoa's model and Hart et al.'s results we predict that stimulus-driven effects on emotion are predicted to affect cognitive control negatively, which in turn will then facilitate automatic imitation. We introduced stimulus-driven effects by manipulating the emotional valence of the distracter stimulus and implemented state dependence by requiring participants to produce the prompt in a neutral or emotional manner. If presenting participants with emotional distracters affects automatic imitation as it affects conflict resolution, then emotional distracters should reduce automatic imitation compared to neutral distracters. With respect to emotional prompts, we predicted that

emotional prompts facilitates automatic imitation compared to neutral prompts. We conducted an experiment in which we varied the emotional valence (neutral, happy, or angry) of the distracter and the prompt. We did so in a series of eight SRC tasks that were designed to be combined into a full factorial design. This full factorial design allowed us to tease apart individual effects of emotional valence of the distracter and prompt as well as the interaction between both factors.

Methods

Most of the past studies relating emotional valence and cognitive control used neuroscience methods (electroencephalography, EEG, and functional Magnetic Resonance Imaging, fMRI), and it was therefore not straightforward to decide on a sample size for our behavioural study. Zinchenko et al. tested 24 participants in their EEG experiment, Hart et al. tested 14 participants in their fMRI experiment, Kanske & Kotz (2010) and (2011) tested 26 participants per EEG experiment. Behavioural automatic imitation for speech experiments also varied considerably in their sample sizes per experiment: Kerzel & Bekkering tested eight participants, Jarick & Jones (2009) tested 42 participants, Roon & Gafos (2015) tested 38 and 35 participants. Galantucci, Fowler & Goldstein (2006) tested 24, 42, and 24 participants, respectively. Only Galantucci et al. provide effect sizes for their results, and these sizes range from small to medium-sized for the relevant effects. We therefore decided to select a number toward the higher end of the studies surveyed. We tested 40 participants (18 male, mean 26.1y, SD 6.4y, range 19-45y). One additional participant was replaced for making >20% errors. All participants had minimum high school-level education, with the majority currently studying at University level. Experiments were undertaken with the understanding and written consent of each subject, according to University College London Research Ethics Committee (UREC, #0599.001).

We used six videos recorded for a female actor from Zinchenko et al. (2015). These included two neutral videos in which the actor said *aa* or *oo* with a *neutral* facial expression, plus four emotional videos: one in which she said *oo* with an *angry* facial expression, one in which she said *aa* with an *angry* facial expression, one in which she said *oo* with a *happy* facial expression, and one in which she said *aa* with a *happy* facial expression (Table 1). We refer to Zinchenko et al. (2015) for a detailed description of the recording procedure and video specifics. The audio was muted using iMovie running on an iMac.

Incongruent and congruent trials were created using written visual prompts that appeared over the mouth of the actor. These prompts were jpeg images with a resolution of 300dpi, .38x.16cm (45×19 pixels) and consisted of white boldfaced Arial font centred on a black background: *aa*, *oo*, *happy*, *angry*. The neutral videos had a duration of 1240ms each and the emotional videos had a duration of 1480ms each. In the neutral videos, the prompt was displayed at four equally spaced SOAs (Stimulus Onset Asynchrony), (Adank, Nuttall, Bekkering, & Maegherman, 2018; Kerzel & Bekkering, 2000), in the video of 240, 490, 740, 990ms, and the SOAs for the emotional videos were set at 240, 490, 860, 1170ms. We decided to keep the videos at their original lengths, as it was not feasible to reduce the emotional videos to the length of the neutral videos without also eliminating observable movement.

The experiment was conducted in a sound-attenuated and light-controlled booth. The stimuli appeared on a PC monitor located 50cm away from the participant's face. Stimuli were presented using Presentation (Neurobehavioral Systems). Audio was played through Sennheiser HD25 SP-II headphones. Participants' responses were recorded via voice key in Presentation, using a Røde microphone plugged into a Scarlett pre-amplifier connected to the USB input of the test PC. RTs were measured from

prompt onset. When no response had been detected after 2500ms from the start of the video, participants received a *no response* warning. Responses were recorded onto the PC's sound card and used to verify that participants had produced the correct response. Moreover, these recordings were acoustically analysed, to establish whether and how participants changed their speech between neutral and emotional conditions.

We designed a series of eight tasks in all of which the participants produced the vowel *aa* or *oo* in a neutral, happy or angry voice, in the presence of a (silent) distracter video depicting someone producing *aa* or *oo* with a neutral, happy or angry facial expression. These tasks were designed so that they could be combined into a full factorial design in which we could probe the individual effect of the two factors Prompt Valence (neutral or emotional) and Distracter Valence (neutral or emotional), and their interaction, on automatic imitation as measured by the facilitation for congruent prompt-distracter stimulus pairs relative to incongruent pairs. Neutral and emotional prompts and distracters were presented in all combinations required to ensure that data was collected for each level of the two factors Prompt Valence and Distracter Valence. Participants completed eight SRC tasks combined into the four conditions NN (Neutral prompt, Neutral distracter), NE (Neutral prompt, Emotional distracter), NE (Neutral prompt, Emotional distracter, EE (Emotional prompt, Emotional distracter) making up the 2×2 factorial design (Figure 1). By comparing the following contrasts, we were able to assess the individual effect of valence of the prompt, distracter, and their interaction: [NN and EN] vs. [NE and E] probed the effect of emotional valence of the distracter on automatic imitation and [NN and NE] vs. [EN and EE] established the effect of emotional valence of the prompt.

Figure 1. Distracters and prompts in the eight tasks, composition of the conditions, and factorial design, ‘-’: *neutral*, ‘+’: *emotional*.

In tasks 1 and 2 (Figure 2), participants produced *aa* and *oo* at a neutral tone of voice, in the presence of two neutral distracter videos of the speaker saying *aa* or *oo*. Tasks 1 and 2 thus represent a standard spoken neutral SRC paradigm (cf., Adank et al., 2018). Task 2 was identical to task 1 and was included to ensure that NN would contain the same number of trials as the other four conditions, which combined the trials of two tasks each. Collecting responses for neutral distracters and neutral prompts in a single task in condition NN only would have resulted in a lower number of trials in this condition than the other three conditions, so the task was repeated to avoid this confound. Tasks 3 and 4 were combined into condition NE, and participants produced neutral prompts *aa* and *oo* in the presence of emotional distracters. Task 3 used happy *aa* and *oo* distracters and task 4 used angry *aa* and *oo* distracters. Tasks 5 and 6 were combined into condition EN. In task 5, the participants spoke *aa* or *oo* in a happy tone of voice in the presence of neutral *aa* and *oo* distracters. In task 6, the participants spoke *aa* or *oo* in angry tone of voice in the presence of the neutral *aa* and *oo* distracters.

Tasks 7 and 8 were combined into condition EE and participants spoke emotional prompts *aa* and *oo* in the presence of emotional *aa* or *oo* distracters. In task 7, participants spoke the vowel *aa* in a happy or angry tone of voice in the presence of happy or angry *aa* distracters. In task 8, participants produced the vowel *oo* in a happy or angry tone of voice in the presence of happy or angry *oo* distracters.

To enable distinguishing between the emotional valence of the distracter and prompt we combined two types of incongruence - vowel and emotional incongruence - had to be combined in the design. Vowel incongruence occurred in experimental tasks that presented participants with a distracter stimulus that showed a difference in the vowel identity between the distracter and the prompt. For instance, in a trial with vowel incongruence, participants might see a video of the speaker saying *oo*, while they are instructed to speak the prompt *aa*. Moreover, to establish how emotional prompt valence affected automatic imitation, participants were to produce the prompt in an emotional tone of voice, e.g., *happy* or *angry*, in the presence of a congruent, or incongruent emotional distracter. For incongruent emotional distracters, participants, for instance, saw a video of the speaker saying a vowel in a *happy* tone of voice, and were requested to respond by producing the same vowel in an *angry* tone of voice. In the experiment, we ensured that the two types of incongruence were not combined in any of the conditions, thus avoiding the confound of having to process vowel and emotional incongruence in a single SRC task. Tasks 1-6 contain vowel incongruence, while tasks 7-8 contain emotional incongruence. In task 7 participants only responded with an angry or happy *aa* prompt and in task 8 participants responded with an angry or happy *oo* prompt.

Specific instructions were provided on-screen per task, prior to a practice session of five trials. Participants were instructed to speak the prompt aloud as fast as possible,

ignoring the distracter video (Figure 3). For the neutral prompts *aa* and *oo*, used in tasks 1, 2, 3, and 4 (Figures 1 and 2), participants were instructed to speak the instructed vowel as soon as they had seen the prompt, at a neutral tone of voice. For the emotional prompts *angry* and *happy*, used in tasks 5, 6, 7, and 8, participants were instructed to speak the vowel specific to that task as soon as they had seen the prompt, at the depicted emotional tone of voice. The experimenter left the room after the familiarisation session. Each task consisted of 80 trials and participants performed all eight tasks, resulting in 640 trials in total. Participants could take a short break every 40 trials. Stimulus lists were randomised per participant and the order of the tasks was randomised across participants. The experiment lasted approximately 40 minutes. Data and program code will be deposited on the Open Science Framework, under the name *SRC_Emotional_Vowels*.

Figure 2. Stills of congruent and incongruent stimuli used in the eight tasks.

Figure 3. Example of the timeline of an incongruent stimulus pair used in tasks 1 and 2 with neutral *oo* prompt and neutral *aa* distracter.

RTs were measured from prompt onset. Errors were excluded from the RT analysis. Errors were defined as too early or late (i.e., faster than 100ms or slower than 1400ms after the onset of the prompt), absent or partial responses, plus trials in which participants produced an incorrect prompt or multiple prompts. Editing of sound files was conducted by a research assistant blind to the Congruence condition. Errors were double-checked by a phonetically-trained listener. RTs were log-transformed before entered into the statistical analyses (Baayen, 2008). We conducted a $2 \times 2 \times 2$ repeated-measures factorial ANOVA on the log-transformed RTs, including factors Congruence (congruent vs. incongruent), Distracter Valence (neutral emotional: [NN and EN] vs. emotional [NE and EE]), and Prompt Valence (neutral [NN and NE] vs. emotional [EN and EE]). Factorial designs offer a flexible and powerful approach allowing for direct scrutiny of main effects and their interactions (Collins, Dziak, Kugler, & Trail, 2014). Note that our study was not designed to directly compare effects of the individual eight tasks on automatic imitation. See Figure 1 for a clarification of how the eight individual

tasks were collapsed into the four conditions NN, NE, EN, and EE. Finally, follow-up tests were performed as needed and controlled for multiple comparisons (Bonferroni).

Second, we measured acoustic characteristics of the speech response to establish whether and how participants changed their utterances between neutral and emotional prompts. Acoustic analysis of recorded responses was conducted in Praat (Boersma & Weenink, 2001). We predicted that duration, intensity, and f_0 would vary between neutral and emotional conditions (Scherer, 2003). Duration was measured in milliseconds (ms), intensity was measured in dB SPL (Sound Pressure Level). Fundamental frequency (f_0) was measured in hertz (Hz) using Praat's default procedure (autocorrelation). Any intensity or f_0 measurements values larger or smaller than three standard deviations per participant were excluded. The three acoustic variables were analysed separately using the same procedure as the RTs. The results were analysed collapsed across response vowel (*aa* or *oo*) and emotion (angry or happy) as a consequence of the specific design of the eight tasks. It was not feasible to split the data according to vowel or emotion as a consequence of the chosen design, as tasks 7 and 8 required participants to produce a single vowel, and in tasks 3-6 a single emotion was presented to participants.

Results

Participants made 6.5% errors (2.2% late responses, 1.9% wrong responses, 1.8% missing responses, 0.5% early responses). Errors were excluded from the RT analysis. The repeated-measures ANOVA on log-transformed RTs reported a main Congruence effect, with slower RTs for incongruent than for congruent stimulus-response pairs (Figure 4, Tables 1 and 2). A main effect was found for Distracter Valence; slower RTs were measured for emotional (NE and EE) than for neutral distracters (NN and EN). Another main effect was reported for Prompt Valence, slower RTs were measured for

emotional (EN and EE) than for neutral prompts (NN and NE). The interaction between Prompt Valence and Congruence was not significant, indicating that emotional valence of the distracter did not affect automatic imitation. Importantly, the interaction between Prompt Valence and Congruence was significant. The interaction between Prompt Valence and Distracter Valence was further investigated using a repeated-measures ANOVA on the automatic imitation effect as indexed by difference scores (Figure 5). We calculated the difference scores by subtracting the log-RTs for the congruent trials from the incongruent trials. Follow-up t-tests showed that the main effect for Prompt Valence could be traced to larger automatic imitation effects for NE than for EN ($p=0.003$). A final series of t-tests established that the overall log-RTs for both congruent and incongruent trials were significantly slowed down for condition EE relative to the other three conditions ($p<0.001$). There were no differences between the respective log-RTs associated with congruent and incongruent trials of the other three conditions (Figure 4).

A follow-up repeated-measures ANOVA on the log-RT values for Condition (NN, NE, EN, EE) combined for congruence level, showed significant differences between the four conditions ($F[3,117]=53.39, p<0.001, \eta^2_{part}=0.58$). This analysis was conducted to ensure that the enhanced automatic imitation effect was not attributable to overall increased effortful processing associated with producing an emotional prompt. Follow-up t-tests showed that responses for EE were slower than for the other three conditions, but that no other comparison was significantly different from one another ($p<0.0125$). Importantly, these results show that there was no difference in log-RT between conditions EN and NN and EN and NE, meaning that producing an emotional prompt in condition EN did not slow down overall task performance. It seemed thus unlikely that increased automatic imitation for emotional prompts was

attributable to increased effort. In summary, the results show facilitated automatic imitation for emotionally produced prompts, irrespective of the emotional valence of the distracter, while the emotional valence of the distracter did not affect automatic imitation.

Figure 4. Mean response times per condition, error bars: 1SE. NN: Neutral prompt, Neutral distracter, NE: Neutral prompt, Emotional distracter, EN: Emotional prompt, Neutral distracter, EE: Emotional prompt, Emotional distracter.

Figure 5. Mean automatic imitation effects in milliseconds (ms) per condition; measured as difference between incongruent and congruent trials, error bars: 1SE, * = $p < 0.05$, ** = $p < 0.005$. NN: Neutral prompt, Neutral distracter, NE: Neutral prompt, Emotional distracter, EN: Emotional prompt, Neutral distracter, EE: Emotional prompt, Emotional distracter.

Table 1. Average response times (RT) in milliseconds plus standard deviations (SD) for congruent and incongruent stimulus pairs, per task, collapsed into four conditions.

Condition	Congruence	RT	SD	Task	Congruence	RT	SD
NN	Congruent	559	154	Task 1	Congruent	589	154
					Incongruent	586	150
	Incongruent	586	147	Task 2	Congruent	558	154
					Incongruent	586	144
NE	Congruent	578	163	Task 3	Congruent	572	162
					Incongruent	600	152
	Incongruent	603	160	Task 4	Congruent	584	165
					Incongruent	607	168
EN	Congruent	569	165	Task 5	Congruent	569	164

					Incongruent	610	170
	Incongruent	607	168	Task 6	Congruent	569	166
					Incongruent	605	167
	Congruent	665	168	Task 7	Congruent	656	185
					Incongruent	708	186
EE	Incongruent	708	188	Task 8	Congruent	673	189
					Incongruent	709	189

The repeated-measures ANOVA (cf. Table 2) for the Duration measurements showed no Congruence effect. A main effect was found for Distracter Valence: participants produced longer prompts for emotional distracters in conditions NE and EE (435ms) compared to neutral distracters (414ms) in conditions NN and EN. Another main effect was found for Prompt Valence: participants produced longer responses for emotional prompts (conditions EN and EE, 468ms) compared to neutral prompts (conditions NN and NE, 381ms). The results showed an interaction between Distracter Valence, Prompt Valence, and Congruence. However, the locus of this interaction could not be traced, as a follow-up repeated-measures ANOVA on the Duration values for Condition (NN, NE, EN, EE), combined for congruence level, was not significant ($F[3,117]=53.39$, $p=0.064$, $\eta_{2part}=0.06$). A final follow-up t-test showed that duration differences were larger for emotional prompts than emotional distracters ($p=.003$)

Intensity measurements showed a main effect of Distracter Valence: participants produced the prompt at higher intensities for emotional distracters (NE and EE, 67.5dB) compared to neutral distracters (NN and EN, 67.1dB). A second main effect was found for Prompt Valence, participants produced emotional prompts at higher intensities (EN and EE, 68.9dB) compared to neutral prompts (NN and NE, 65.8dB). No other effects were found. A follow-up t-test showed that intensity differences were larger for emotional prompts than emotional distracters ($p<.001$).

The ANOVA for f_0 measurements showed a main effect of Distracter Valence, participants produced the prompt with a higher f_0 for in the presence of an emotional distracter (NE and EE, 1189Hz) than in the presence of a neutral distracter (NN and EN, 184Hz). A second main effect was found for Prompt Valence: participants produced the prompt with a higher f_0 in conditions with an emotional prompt (EN and EE, 204Hz) than in conditions with a neutral prompt, (EN and EE, 169Hz). Third, the significant interaction between Distracter Valence and Prompt Valence indicated that for emotional prompts, a larger difference between emotional and neutral distracters (39Hz) was found than for neutral prompts (1Hz). A final t-test showed that f_0 differences were larger for emotional prompts than for emotional distracters ($p < .001$). In sum, participants produced longer emotional prompts at a higher intensity and a higher f_0 , than neutral prompts. In addition, they produced longer prompts at a higher intensity and with a higher f_0 when the distracter was emotional, and this difference was larger when the prompt was also emotional, for f_0 only.

Table 2. Results for the ANOVAs on response times (RT), Intensity, and f_0 measurements. Significant results indicated in **boldface**.

FACTOR	RT	DURATION	INTENSITY	f_0
<i>Congruence</i>	$F[1,39]=170.7$, $p<0.001$, $\eta_{2part}=0.81$	$F[1,39]=1.56$, $p=0.22$, $\eta_{2part}=0.04$	$F[1,39]=4.0$, $p=0.052$, $\eta_{2part}=0.09$	$F[1,39]=0.6$, $p=0.453$, $\eta_{2part}=0.01$
<i>Distracter Valence</i>	$F[1,39]=89.7$, $p<0.001$, $\eta_{2part}=0.7$	$F[1,39]=5.29$, $p=0.027$, $\eta_{2part}=0.04$	$F[1,39]=6.7$, $p=.013$, $\eta_{2part}=0.18$	$F[1,39]=6.0$, $p=0.019$, $\eta_{2part}=0.13$
<i>Prompt Valence</i>	$F[1,39]=42.2$, $p<0.001$, $\eta_{2part}=0.52$	$F[1,39]=22.4$, $p<0.001$, $\eta_{2part}=0.37$	$F[1,39]=49.8$, $p<.0001$, $\eta_{2part}=0.56$	$F[1,39]=66.3$, $p<0.001$, $\eta_{2part}=0.63$

<i>Distracter Valence × Congruence</i>	$F[1,39]=2.0$, $p=.169$, $\eta_{2part}=0.05$	$F[1,39]=0.214$, $p=0.254$, $\eta_{2part}=0.03$	$F[1,39]=2.0$, $p=0.164$, $\eta_{2part}=0.05$	$F[1,39]=0.0$, $p=0.991$, $\eta_{2part}=0.0$
<i>Prompt Valence × Congruence</i>	$F[1,39]=9.7$, $p=0.003$, $\eta_{2part}=0.2$	$F[1,39]=0.064$, $p=0.8$, $\eta_{2part}=0.002$	$F[1,39]=0.8$, $p=0.367$, $\eta_{2part}=0.02$	$F[1,39]=1.38$, $p=0.247$, $\eta_{2part}=0.03$
<i>Distracter Valence × Prompt Valence</i>	$F[1,39]=34.9$, $p<0.001$, $\eta_{2part}=0.47$	$F[1,39]=.214$, $p=0.65$, $\eta_{2part}=0.005$	$F[1,39]=0.5$, $p=0.476$, $\eta_{2part}=0.01$	$F[1,39]=5.8$, $p=0.021$, $\eta_{2part}=0.13$
<i>Congruence × Distracter Valence × Prompt Valence</i>	$F[1,39]=0.05$, $p=.821$, $\eta_{2part}=0.001$	$F[1,39]=7.62$, $p=0.009$, $\eta_{2part}=0.16$	$F[1,39]=0.0$, $p=0.905$, $\eta_{2part}=0$	$F[1,39]=0.2$, $p=0.669$, $\eta_{2part}=0$

Discussion

This study aimed to determine the effect of emotional valence on automatic imitation of visual speech. We found facilitated automatic imitation for emotional prompts, but not emotional distracters, relative to neutral prompts. Our results for emotional prompts extended results reported in Hart et al. (2010) to automatic imitation and confirmed predictions from Pessoa (2009). However, the prediction that automatic imitation would be attenuated for emotional distracters was not confirmed. We based this prediction on past result from conflict resolutions studies that showed facilitation for emotional distracters (Kanske & Kotz, 2010, 2011; Xue et al., 2013; Zinchenko et al., 2015). The discrepancy between our results and those of past studies could be due to differences between the SRC task used in our study and the Flanker, Simon, and Stroop tasks used in past studies. The main difference between the SRC task and the other tasks is that participants produce a specific goal-directed action in response to the prompt, instead of a button press. It is not clear to which extent conflict resolution and automatic imitation dissociate, but a meta-analysis of 47 neuroimaging studies showed

differences in the neural signature of the SRC task compared to the other tasks (Nee, Wager, & Jonides, 2007). SRC tasks were mostly associated with activation in premotor and cingulate areas, while no premotor activation was reported for the Flanker and Stroop tasks included. Execution of goal-directed actions in the SRC task invoked a neural network associated with action execution more than the other tasks. Emotional information could interact with goal-directed actions in the SRC task at a later stage of action planning and execution than in other tasks, but this assertion is to be confirmed experimentally.

Moreover, the cognitive mechanism through which emotion affects automatic imitation is unclear. General mood and anxiety affect cognitive control (Eysenck & Calvo, 1992; Knolle, Schröger, & Kotz, 2013; Pessoa, 2009), and efficiency of cognitive control affects automatic imitation (Catmur, 2016; Chong et al., 2009; van Leeuwen et al., 2009). Our results indicate that emotional state dependence affects automatic imitation. Our results further provide support for the hypothesis that emotional valence could affect automatic imitation mediated through cognitive control processing. Confirmation of this hypothesis would imply that emotional state dependence only affects automatic imitation when cognitive processing is also affected. However, it is currently not feasible to verify this hypothesis, as there exists a lack of studies investigating the effect of emotional valence on automatic imitation. Specifically, to our knowledge, ours is the first experiment in which the effect of emotional versus neutral distracters was explored systematically and further study is required to validate our findings.

Our results for emotional distracters disagree with results from studies showing that observing an emotional action, such as an emotional facial expressions (Dimberg, Thunberg, & Elmehed, 2000) or emotional speech (Neumann & Strack, 2000), leads

participants to imitate these actions. Participants in Dimberg et al. activated the congruent facial muscles (as measured using electromyography, EMG) when exposed to smiling or frowning facial expressions, and participants in Neuman & Strack produced speech samples with intonation patterns congruent with emotional speech sample they were exposed to. We found no such imitative patterns in our response times, nor in our acoustic measurements (but it should be noted that the study was not designed to allow for detailed acoustic scrutiny of imitative speech patterns). We also did not measure muscle activity using EMG, and we can therefore not exclude the possibility that emotional valence of the distracter did not result in an imitative response in participants.

Yet, while a null result was found for distracter emotional valence, the emotional prompt valence was found to affect automatic imitation. It seems unlikely that facilitation of automatic imitation could be due to increased task effort. If this were the case, then overall task performance in condition EN should be slower than the two conditions with neutral prompts (NN and NE), which was not the case. It should be noted that it is not feasible to completely exclude any attentional or effort effects on automatic imitation. However, it should be noted that this is a general issue for studies focusing on processing of emotional versus neutral stimuli in, for instance, the conflict resolution literature (Kanske & Kotz, 2010, 2011; Zinchenko et al., 2015; Zinchenko, Obermeier, Kanske, Schröger, & Kotz, 2017). Emotional stimuli tend to be more arousing than neutral stimuli, and processing of emotion may be regarded as intrinsically confounded with cognitive or attentional load, with more emotionally arousing stimuli capturing attention to a larger degree (Ohman, Flykt, & Esteves, 2001). It is unclear to which extent automatic imitation is affected by cognitive load, as the result from current studies are not conclusive. One study reports that increased

cognitive load facilitates automatic imitation (van Leeuwen et al., 2009), while a second study reports inhibited automatic imitation for increased cognitive load conditions (Catmur, 2016). Therefore, the specific relations between attention, emotion, and automatic imitation are poorly understood and need to be elucidated in further research.

The cognitive mechanisms through which the production of emotional speech leads to facilitation of automatic imitation are also unclear. One possibility is that being required to produce an emotional stimulus resulted in a (small and temporary) change in the emotional state of the participants. For facial expressions, this concept is also referred to as the *facial feedback hypothesis* (Strack, Martin, & Stepper, 1988). This hypothesis predicts that our facial expression affects our affective experience. Thus it predicts, for example, that being required to smile leads to an increase in feeling of happiness. A recent meta-analysis found tentative support for this hypothesis (Coles & Larsen, 2017). Yet, as we did not measure any changes in affective mood associated with producing the emotional prompts, we cannot be sure that participants experienced any changes in mood during vowel production. However, we found that participants changed their speech acoustically when producing emotional versus neutral prompts. Emotional prompts were produced with longer durations, at a higher intensity and with a higher f_0 , than neutral prompts. Also, these acoustic changes were not accompanied by slower response times for the conditions NE (Neutral Prompt, Emotional Distracter), EN (Emotional Prompt, Neutral Distracter), relative to condition NN (Neutral Prompt, Neutral Distracter), indicating that the change in speech production did not necessarily relate to increased attention or effort associated with the emotional status of the stimuli. However, it remains to be elucidated how and hypothesized change in emotional status in conditions EN and EE could have resulted in facilitated automatic imitation. Predictions based on Pessoa's model (2008, 2009) and results from Hart et al. suggest

that state dependent effects downregulate cognitive control systems. In Hart et al., the emotional valence of the prime slowed down processing of the incongruent distracter in a Stroop task. We found slower response times associated with both congruent and incongruent distracters for condition EE relative to the other three conditions, so our results do not show clear evidence for downregulation of cognitive control systems. Instead, the facilitation of automatic imitation appeared to be due to larger differences between incongruent and congruent trials in conditions EN and EE relative to conditions NN and NE.

In conclusion, our results have implications for theories of action imitation and conflict resolution. Theories on the relation between emotion and cognitive control need to be extended to account for imitative behaviour, and thus to sensory and motor action associations to fully account for the role of emotional valence associated with everyday communicative actions (Pessoa, 2008, 2009). Furthermore, models accounting for imitative behaviour such as ASL (Heyes, 2011) could be extended to explain effects of emotional valence on automatic imitation, as well as effects of general executive (cognitive) factors. In sum, emotional state dependence affected automatic imitation: suppression of the tendency to automatically replicate an observed action was less efficient when producing emotional goal-directed actions.

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