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# Knowing How You Are Feeling Depends on What's on My Mind: Cognitive Load and Expression categorisation

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## Abstract

The ability to correctly interpret facial expressions is key to effective social interactions. We are well rehearsed and generally very efficient at correctly categorising expressions. However does our ability to do so depend on how cognitively loaded we are at the time? Using repeated measures designs we assessed the sensitivity of facial expression categorisation to cognitive resources availability by measuring people's expression categorisation performance during concurrent low and high cognitive load situations. In Experiment1 participants categorised the six basic upright facial expressions in a 6-AFC response paradigm whilst maintaining low or high loading information in working memory (*N*= 40; 60 observations per load condition). In Experiment 2 they did so for both upright and inverted faces (*N*= 46; 60 observations per load and inversion condition). In both experiments expression categorisation for upright faces was worse during high versus low load. Categorisation rates actually improved with increased load for the inverted faces. The opposing effects of cognitive load on upright and inverted expressions are explained in terms of a cognitive load related dispersion in the attentional window. Overall the findings support that expression categorisation is sensitive to cognitive resources availability and moreover suggest that, in this paradigm, it is the perceptual processing stage of expression categorisation that is affected by cognitive load.


**Keywords**: Facial expression categorisation, working memory load, cognitive load, attentional window, affect processing.

# Knowing How You Are Feeling Depends on What's on My Mind: Cognitive Load and Expression categorisation

Facial expressions provide valuable socially relevant information. Not only do they offer insight into a person's affective state, such as if they are angry or happy, but they also influence social judgments such as a person's approachability or attractiveness and our empathetic response to them (Ickes, 1993; Willis, Palermo, & Burke, 2011). The ability to categorise facial expressions correctly and respond appropriately to them is critical for affective social interactions. Within social psychology, expression processing has been addressed from a multitude of approaches. One perspective has been to investigate the effect of local elements such as stimuli dimensions and presentation time, which are found to affect expression categorisation (for a review see Derntl, Seidel, Kainz & Carbon, 2009). Whilst the sensitivity of expression categorisation to more distal factors such as trait judgments of the emotion expresser (Said, Haxby & Todorov, 2011) and individual differences in the judger's interpersonal sensitively (Hall, Andrzejewski &Yopchick, 2009) is also well documented. Thus evidence suggests that a combination of both local and distal factors ultimately determine expression categorisation ability. Here we employ a local level approach to investigate if facial expression categorisation occurs automatically or whether cognitive resources are required to make judgments. As reviewed below this is an important aspect of expression categorisation that requires further clarification.

## Automaticity of Affect Processing

It has long been established that regardless of race and culture we are all remarkably adept at recognising certain basic emotions (Ekman, Sorenson & Friesen, 1969). This, together with the seemingly effortlessness, speeded (Lui, Harris & Kanwisher, 2002) and in certain situations unconscious (Dimberg, Thunberg & Elmehed, 2000) and unavoidable (Vuilleumier, Armony, Driver & Dolan, 2001) processing of facial affect has led to the presumption that the process occurs automatically. However more recent findings have challenged this view. For instance the fact that, perception and affective response to emotive images can be modulated by individual differences (e.g. Nowicki & Duke, 1994; Hall, Andrzejewski &Yopchick, 2009), social relevance (e.g. Bublatzky, Gerdes, White, Riemer & Alpers, 2014), and cultural rearing (Biehl et al., 1997), suggests that the process is not fully automatic (for detailed reviews see Palermo & Rhodes, 2007; Okon-Singer, Lichtenstein-Vidne & Cohen, 2013).

A key assessment of a process' automaticity is its reliance on cognitive resources (Shiffrin & Schneider, 1977; Kahneman & Treisman, 1984; Bargh, 1994). Findings from clinical populations support that processing of facial expressions fails this test of automaticity. For example, reductions in cognitive resources due to aging (Ruffman, Henry, Livingstone & Phillips, 2008) and brain injury (Yim, Babbage, Zupan, Neumann, & Willer, 2013) have been associated with reduced facial expression judgments. The automaticity of a process in healthy populations is typically assessed by imposing concurrent cognitive load to temporarily reduce cognitive resource availability. If the process occurs equally well during no or low load conditions compared to high load conditions, it can be inferred that the process is not reliant on cognitive resources and thus occurs automatically. Such manipulations have been employed to examine the automaticity of affect processing from various avenues, these will be briefly reviewed before highlighting the motivation to investigate the relation between facial expression categorisation and cognitive load in the current studies.

Erk, Kleczar and Walter (2007) presented task irrelevant emotional stimuli between the presentation and test phase of a short-term memory task. The neural response to the valence stimuli was reduced in difficult versus easy versions of the memory trials. In Van Dillen, Heslenfeld and Koole's (2009) paradigm the valent stimuli was presented first, then the cognitive task (easy or difficult arithmetic task). The neural activity in the emotion processing region, amygdala, was attenuated with increased load. And Roman et. al's., (2015) study suggested that secondary task emotional stimuli only influence performance when cognitive resources are not fully occupied by a primary task. Collectively such findings support that the response to emotional stimuli is not automatic but rather sensitive to cognitive resources availability - when people are engaged in cognitively taxing tasks, the neural response to valence information is down-regulated.

It is worth noting that the emotional information is was actually task irrelevant in the above paradigms. What affect might cognitive load have on the emotional stimuli when they are actually relevant to the task? Blair et al. (2007) presented valent stimuli in the presence or absence of a cognitively demanding numerosity task. Although behavioural responses to the valent stimuli were not recorded, the authors urged participants to attend to this information stating that they may be questioned on it later. Kellermann et al. (2012) insured the affective images were perceptually processed by using them as go-cues during low and high cognitive load conditions. In both studies, comparable to the passive viewing studies, the brain's neuronal response to the emotional stimuli was attenuated in the presence of concurrent cognitive load. In Kron, Schul, Cohen and Hassin's (2010) dual task paradigm, participants had to actually report the feeling elicited by valent stimuli. They found the intensity of self-reported feelings were reduced whilst performing a concurrent cognitive load task rather than alone.

Collectively these studies support that the response evoked by valent stimuli during both passive and active viewing is reduced when cognitive resources are drained by a cognitively demanding secondary task. Whilst the modulation of affective response to emotional stimuli as a function of cognitive resources is informative and aids to decipher the automaticity of emotion processing, it does not answer the arguably more ecologically pertinent question of whether conscious recognition of emotional information is impacted when cognitive resources are engaged elsewhere. Are we able to correctly categorise a person's facial expression regardless of our own personal cognitive state? Or are we more likely to make misjudgements when we interact with people in a cognitively loaded versus relaxed state? The current study aims to investigate the dynamic between cognitive load and affect from this alternative perspective, which despite being of prime social relevance has been tackled surprisingly sparsely. A few previous studies have attempted to shed light on the relation, but as reviewed below, there is still scope to further clarify the interplay between cognitive resources and facial expression categorisation.

Tracy and Robins (2008) aimed to evaluate the automaticity of expression categorisation by manipulating two factors; the time allowable to make a response and concurrent cognitive load. Participants were instructed to make a two alternative forced choice response (yes/no) to the target emotion's appearance. Judgments were made under fast, deliberation and concurrent cognitive load conditions (1000ms, 8000ms, and 1500ms to respond respectively). The face stimuli remained on screen until a response was made or the response window had lapsed. The accuracy rates did not differ between the fast and cognitive conditions. However, in comparison to the deliberate condition, categorisation accuracy was comparatively lower in the cognitive condition for fear, sadness and surprise, but not the remaining emotions (anger, contempt, disgust, happiness, and pride). This does indicate that categorisation of particular emotions is impaired by cognitive limitations, however since the response windows were unequal across conditions, interpreting the cause of the differential performance across conditions is problematic. Furthermore the 2-AFC paradigm is not the best representation of real-life expression judgments – we rarely question ‘do these faces look surprised or not?’Rather, we judge which of several pre-existing emotional categories a processed facial expression is closest to.

Philips, Channon, Tunstall, Hedenstrom and Lyons (2008) assessed the impact of cognitive load on this type of expression categorisation ability. They asked people to categorise upright emotions with varying degrees of intensity (50, 75 and 100%) as one of the displayed options (2, 4 or 6 choices) under no load and dual load (2-back task) conditions. Emotion categorisation accuracy was overall lower in the dual compared to no load condition. The load related accuracy deterioration was unaffected by emotion intensity, but the effect increased as a function of the number of response choices. The authors interpreted this to imply that in this scenario perceptual processing of facial emotions are not affected but it is the verbal naming of expressions that is sensitive to cognitive load. However, the paradigm compared no load task performance with dual task. Equating performance change in the dual task to cognitive resource reductions in such comparisons is problematic, as the effects may be due to the distraction effect of the additional secondary task rather than cognitive resources limitations per se (Kron, et al., 2010). Thus direct tests of cognitive load’s effect on expression categorisation have been rare. And whilst previous research suggests that expression categorisation may be sensitive to cognitive load, arguably paradigm limitations restrict the conclusiveness of the effect, warranting further clarification.

## Overview of the Current Research

In the current studies we used a popular expression categorisation task (Ekman, et al., 1969) - participants were presented with a single facial expression and tasked to categorise it as one of the six basic facial emotions (happy, sad, anger, fear, surprise and disgust). The expression was presented for a fixed time of 250ms, followed by the response screen which remained until a response was made. These timings were kept consistent across all conditions and the expression categorisation always occurred in a dual task scenario. The only variable was the degree of concurrent cognitive load. Participants were instructed to retain six sequential (low load) or random numbers (high load) in memory for later recall, comprising the concurrent low and high cognitive load conditions respectively.

In Experiment 1 upright images were used to firstly assess the effect of this cognitive load manipulation on expression categorisation ability. As previous literature implies that expression categorisation is to some degree reliant on cognitive resources (e.g. Tracy & Robbins, 2008; Philips et al., 2008) and secondly previous studies using comparable cognitive load manipulations have found cognitive resources reliant task performance is hindered in the high versus low load condition (e.g. Hester, Murphy & Garavan, 2004; Lavie, Hirst, de Fockert & Viding, 2004), we predicted that expression categorisation would be reduced during high compared to the low concurrent load condition. In line with this prediction, concurrent high compared to low cognitive load did hinder expression categorising in Experiment 1.

In Experiment 2 we attempted to further explore the cause of the deterioration. Recent studies have proposed a cognitive load related dispersion in the attentional window as a mechanism for the reduced performance of cognitive resources reliant visual tasks (e.g.

Ahmed & de Fockert 2012a; Ahmed & de Fockert 2012b). In Experiment 2 we tested whether a similar mechanism was responsible for the altered processing of the socially pertinent visual stimuli used in the current studies i.e. facial expressions.

## Experiment 1

### Method

**Participants**[1]. Forty undergraduate students volunteered to participate in the study as part fulfilment of their course requirement, including 30 females (*M*= 19.97 years, *SD* = 2.17) and 10 males (*M*= 20.40 years, *SD* = 2.88). Twenty six noted their ethnicity as Caucasian, three Asian, five Black Afro Caribbean, three of mixed ethnicity and two ethnicities were undeclared[2]. All had normal or corrected-to-normal vision.

**Apparatus**. The experiment was presented on an individual PC using E-Prime software (Schneider, Eschman, & Zuccolotto, 2002), responses were collected using a standard keyboard. Participants were tested in individual cubicles, seated approximately 50 cm from a 21x28cm monitor.

**Tasks.** The experiment consisted of two components, a WM task and a facial expression categorisation task. Firstly, participants were presented with a string of 6 digits

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[1] For Experiment 1, the required sample size was estimated by using an alpha of .05 and beta of .8. The effect size used (d =0.544), and prediction (one-tailed) was guided by research that used the same WM load manipulations (i.e. six digits in sequential versus random order; Ahmed & deFockert, 2012). These values when entered into G*power (Faul, Erdfelder, Lang, & Buchner, 2007) yielded a required sample size of 24.

[2] Analysis of the expression categorisation task data including ethnicity (Caucasian, non-Caucasian) as an additional between subjects factor was conducted for both Experiments. In both cases the main effect ethnicity and its interactions were non-significant ($p > .2$ and $F < 1.3$ in all cases). See general discussion for further remarks on this point.

either in ascending sequential order (low WM load) or in random order (high WM load) to retain in memory.  The digits were presented horizontally and centrally in 32-point Arial bold font, in white, on a black background. There were four sequential six digit low WM load sequences and 48 random order six digit sequences for the high WM load.

Participants were then presented with the face stimuli and tasked to categorise the expression as one of the six possible options. Finally a single-digit memory probe was presented, requiring a judgment of whether it was ‘present’ or absent’ in the initial digit sequence (see Figure 1). The experiment had a repeated measures design, in that each participant completed the expression categorisation task under both WM load conditions.

[Insert Figure 1 here]

**Materials.** The face stimuli were taken from the NimStim database of Facial Expression images, which have high overall validity (79%) and reliability (between 79-100%) for the expression judgments (Tottenham et al., 2009). The first ten Caucasian male and female individuals were selected from the database, and their expressions representing the six basic emotions; happy, sad, fear, surprise, anger and disgust were included in the Experiment, resulting in a total of 120 images. All images were upright, in colour and of actors, aged between 21- 30 years. The images subtended a visual angle of 16.67° horizontally and 20.83° vertically.

**Procedure.** Ethical approval was achieved from the institutional ethics committee prior to data collection. Informed consent was achieved prior to, and all participants were debriefed following participation.

The WM 6-digit sequence was presented for 2000ms, followed by a 1500ms blank screen, then the face stimuli for 250ms, followed by the facial categorising response screen displaying the 6 possible expression options (1= happy, 2 = sad, 3= fear, 4= surprise, 5= anger and 6 = disgust). Finally the single digit WM probe response screen. The response screens did not have a fixed presentation interval but rather moved on following the participant's response.

On each trial, the 6-digit sequences were randomly selected from the list of 4 or 48 sequences for the low and high WM load sequences respectively. Across the experiment, the WM probe was present or absent in the original sequence equally as often, and when present was equally as likely to occur in any of the 6 digit positions. Participants were instructed to press the 'w' key if they thought the probe had been present and the 's' key if they thought it had been absent in the original sequence. Response mappings were counterbalanced across participants. A series of 5 face stimulus-response screen cycles were presented between the digit sequence and probe screens. The face stimuli were randomly selected from the possible 120 options without repetition.

WM load was manipulated between blocks, with one block of each load presented per experiment. Each WM block consisted of 12 WM, and 60 face trials (i.e. 60 observations per WM load condition). Thus across the experiment participants responded to 120 face stimuli in total (20 of each expression type), half under each WM load condition. WM load block order (e.g. low WM block 1$^{st}$ or 2$^{nd}$) was counterbalanced across participants.

Participants completed a short practice (4 WM trials and 20 face trials per WM block) before commencing the experiment. Incorrect response feedback was provided in the practice but not experimental blocks. Written and verbal instructions urged participants to respond as quickly and as accurately as possible and also that both components of the task were equally as important.

**Data Analysis**

The mean accuracy and RTs for correct WM trials were computed for each individual and are reported for all proceeding analysis. As the main objective is to assess the impact WM load has on expression categorisation, for the Face task accuracy analysis, incorrect memory response trials were excluded to ensure only trials in which participants were performing both tasks were analysed, and the RT analysis was based on correct Face and WM trials only for the same reasoning (see Lavie, Hirst, de Fockert, & Viding, 2004). *p*-values adjusted for one –tailed comparisons are denoted by an asterisk (*). Post hoc t-test analyses were tested against Bonferroni corrected significance levels ($p$ <.025).

**Results**

**WM task**. As anticipated, the accuracy level was higher in the low WM load ($M$ = 87.35%, $SD$ = 1.49) compared to the high WM load trials ($M$ = 81.90%, $SD$ = 1.66). The result of a Paired sample t-test confirmed that the difference was significant, $t(39) = 2.068$, $p$ = .023*, $d$ =0.327. A similar comparison of the mean RTs on correct Low ($M$ = 1860.09, $SD$ = 410.95) and high WM ($M$ = 1765.76, $SD$ = 411.25) trials revealed that RTs did not vary as a function of WM load ($p$ = .087, $t$ = 1.75).

**Expression categorisation task**. Expression categorisation was more accurate when concurrent WM load was low ($M$ = 80.33%, $SD$ = 7.41) compared to high ($M$ = 76.73%, $SD$ = 8.25). RTs during the two WM conditions were very similar, 1478.78ms ($SD$ = 361.65) during low and 1481.86ms (323.97) during high WM load (see Table 1).  The results of paired sampled t-tests revealed that the effect of WM load on RTs was not significant (*p* =.93, *t* = .-09). However the detrimental impact of increased WM load on the ability to categorise expressions correctly was significant, $t(39) = 2.681$, $p = .011$, $d = 0.459$

**Expression type analysis.** Categorisation accuracy levels are known to vary across the six basic facial expressions used (happy, sad, anger, fear, surprise and disgust) (e.g. Ekman, Sorenson, & Friesen, 1969). In order to assess if there was a main effect of expression type and also whether the impact of WM load differed as a function of expression type, we conducted some additional analysis. Two 2x6 ANOVAs, with WM Load (low, and high) and expression type (fear, disgust, sad surprise, anger, happy) (ten observations per expression type cell) as within subjects factors were conducted on the RT and accuracy data.

The main effect of WM load was approaching significance $F(1, 39) = 3.838$ $p = .057$, $\eta^2 = 0.090$. The accuracy ANOVA revealed a strong main effect of expression type, $F(5, 195) = 78.90$, $p < .001$, $\eta^2 = 0.669$. Happy stimuli were the easiest to categorise (96.8%), followed by anger, surprise, sad and disgust. The accuracy of correctly categorising fearful faces was by far the lowest at 50.9% (see Table 2 and Figure 2). The interaction between WM load and expression type was not significant ($p = .2$, $F = 1.47$), indicating that WM load's detrimental impact on categorising faces was indiscriminate of expression type.

The equivalent ANOVA on mean RTs on correct trials revealed a main effect of expression type, $F(5, 195) = 90.264$, $p < .001$, $\eta^2 = .698$. Fastest responses were to happy faces and slowest for fearful faces. The speed of responding to the different faces closely followed the same pattern as the accuracy data, indicating an absence of speed-accuracy trade off (see Table 2). The main effect of WM load, and WM load by expression type interaction were not significant for the RTs ($p = .46$, $F = .57$ and $p = .6$, $F = .73$ respectively).

**Discussion**

In Experiment 1 expression categorisation performance was recorded during low and high concurrent load conditions. In line with previous findings (e.g. Ekman et al., 1969) the ease by which each of the six expressions were categorised varied significantly. Happy stimuli were the easiest to categorise closely followed by anger, surprise, sad and disgust. Fearful faces were categorised the least accurately. The comparative ease of categorising different expressions is sensitive to paradigm specifics such as stimuli dimensions, presentation time and task instructions (for a review see Derntl, et al., 2009). The current pattern of accuracy rates paralleled those of comparable paradigms (such as Derntl et al., 2009; Prkachin, 2003), thus replicating the known differential categorisation accuracies for the basic expressions.

The novel objective of Experiment 1 was to assess the effect cognitive load has on the ability to affectively categorise these facial expressions. The results demonstrated that the speed of responses were the same under the two load conditions; however the accuracy of the judgments were significantly affected by cognitive load. Participants were worse at categorising the expressions during high compared to low concurrent load. Interestingly the interaction between cognitive load and expression type was not significant; indicating that the detrimental impact of cognitive load is similar for the six basic expressions tested. Possible reasons for this are addressed in the general discussion.

The current findings build on preceding literature that infers a relation between expression categorisation and cognitive resources. Previous studies have compared expression categorisation in no load compared to dual task situations, or with varying response windows which limits inferring causality of performance changes directly to reduced cognitive resources (e.g. Tracy & Robbins, 2008; Philips et al., 2008). Since the number of response options, presentation time and response window were all kept consistent in current study, and expression categorisation was always conducted in a dual task scenario; the only variable was the level of cognitive load in the secondary WM task, the hindered expression categorisation in Experiment 1 can be equated more confidently to reduced cognitive resources. Moreover as the reduced expression categorisation in the current study occurred whilst number of response options was kept consistent, it implies cognitive load impacts a stage of expression processing other than response selection. Categorising expressions is a three stage process. Firstly the perceptual information is processed, this is then interpreted as a particular expression, and finally a manual response mapping the interpretation to available options is made. As explained below, we suggest the current cognitive load effects are occurring at the perceptual processing rather than response selection stage.

Visual attention acts like a window or ‘spotlight’, which can be adjusted, allowing us to focus the spotlight on relevant, and ignore irrelevant information (Eriksen & St James, 1986; Jonides, 1983). Several recent studies suggest that increasing cognitive load causes the distribution of the attentional window to become dispersed or spread out. For example, Ahmed and de Fockert (2012b) recorded Flanker task (Eriksen & Eriksen, 1974) performance during concurrent low and high cognitive load. In this task participants respond to a central target whilst ignoring peripheral distracting information. The pattern of interference from peripheral distractors indicated that the profile of the attentional window was more spread out (more global) when concurrent cognitive load was high compared to low. This cognitive load related dispersion of the attentional window was further assessed utilising the Navon paradigm (Ahmed & de Fockert, 2012a). Navon letters are hierarchical global stimuli that are made up of smaller local level ones (Navon, 1977). Participants found it easier to attend to the global letter under high compared to low load, and more difficult to do so when attending to the local letter– both effects additionally support a dispersion of the attentional window as a function of cognitive load. Similar effects were also reported by Marguc, Forester and Van Kleef (2011). The authors cognitively loaded their participants by asking them to solve demanding or easy anagrams before completing a Navon task - performance on the subsequent Navon task demonstrated that the attentional setting was more global following the demanding rather than easy situation. Finally Van der Linden and Eling (2006) using a different measure of cognitive depletion; mental fatigue, found a similar effect of cognitive limitations on attentional settings. Thus substantial evidence supports that depletion in cognitive resources can cause the attentional window to become more dispersed or spread out. As explained below, we suggest that this phenomenon underlies the reduced expression categorisation with increased cognitive load recorded in Experiment 1.

It is known that rather than processing individual features of faces (e.g. eye and nose) analytically, we typically process the whole face as a gestalt (Young, Hellawell & Hay, 1987; Tanaka & Farah, 1993). The same applies for facial expressions; the optimal (and consequently default) setting for facial expression processing is typically holistic (e.g. Calder, Young, Keane & Dean, 2000; Tanaka, Kaiser, Butler & Le Grand, 2012). A plausible explanation for the observed decline in expression categorisation during high load is that the cognitive load related dispersion in the attentional window spreads the attentional setting away from the default ideal global setting. This ‘over globalisation’ of the attentional window is what makes it harder to correctly categorise expressions during high compared to low cognitive load. Evidence congruent with this proposal is evident in Martin, Slessor, Allen, Phillips and Darling’s (2012) study. The authors measured facial expressions categorising after the attentional setting was altered by priming. Compared to local priming, the ability to correctly identify expressions in upright faces was reduced when attention was dispersed by global priming. This pattern is comparable to the reduction in expression categorisation for upright faces under high WM load in the current study and supports that this effect may be due to a dispersion of the attentional setting.

In Experiment 2 we used both upright and inverted faces to further corroborate the attentional dispersion account. Ample evidence supports that face orientation solicits different processing styles; upright faces are processed in a task adaptive holistic manner, whereas inversion impedes this naturalistic holistic processing of faces and promotes more local or feature based processing, which is a less appropriate setting for expression categorisation (Yin, 1969; Young et al., 1987; Calder et al., 2000). The differential attentional settings accompanying these stimuli types provides an excellent test for the notion that cognitive load causes a dispersion in the attentional window.

In Experiment 2, for upright faces, cognitive load is anticipated to disperse attention away from the optimal global setting, and as in Experiment 1 expression categorisation accuracy is predicted to be lower under high compared to low load. However, for inverted faces, high cognitive load is predicted to shift processing from the inversion solicited local setting to a more task appropriate holistic setting, consequently improving expression categorisation in inverted faces. Thus if the decline in expression categorisation is a result of cognitive load related dispersion in the attention window, then differential effects of cognitive load are anticipated for the upright and inverted faces.

## Experiment 2

In Experiment 1 participants responded to upright faces under concurrent low and high WM load. In Experiment 2 the additional factor of orientation was included. A within subjects 2x2 design was used to record expression categorisation for the six emotions, in both upright and inverted faces, under concurrent low and high WM load.

## Method

**Participants**[3]. Forty six undergraduate students volunteered to participate in the study as part fulfilment of their course requirement, including 25 females (*M*= 22.96 years, *SD* = 4.93) and 21 males. Thirty nine noted their ethnicity as Caucasian, three Asian, two Black Afro Caribbean and two as Arabic. All had normal or corrected-to-normal vision (see footnote 2).

**Materials and Procedure**. The upright condition was the same as Experiment 1. The inverted condition was also the same, with the exception that the 120 images were presented following a 180° rotation. Thus there were 60 observations per WM load and inversion condition. Condition type (e.g. Upright condition 1st or 2nd) was counter balanced across participants. Participants completed the 2nd condition 2 weeks after completing the 1st. See Figure 1 for sample of upright and inverted images. Once again, a repeated measures design was employed, in that each participant completed the expression categorisation task under both WM load and inversion conditions.

## Results

[3] For Experiment 2's within subjects factorial design, the sample size required for the theoretically pertinent effect (i.e. interaction) was estimated by using an alpha of .05 and beta of .8. The observed effect size for the expression categorisation task in Experiment 1 (d =.459) and a two-tailed prediction was used. The calculation yielded a sample size of 30.

**WM task**. A repeated measures 2x2 ANOVA with Face Orientation (upright, inverted) and WM load (low, high) was conducted to assess memory performance across conditions. The main effect of WM load was significant; $F(1,45) = 21.604$, $p < .001$, $\eta^2 = 0.324$. As in Experiment 1, the mean accuracy rates were higher when concurrent WM load was low ($M = 87.39\%$, $SD = 11.36$) compared to high ($M = 78.21\%$, $SD = 13.11$). Accuracy rates were higher during upright compared to inverted trials ($M = 84.96\%$, $SD = 11.13$ and $M = 80.83\%$, $SD = 12.40$) respectively, $F(1,45) = 6.121$, $p = .016$, $\eta^2 = 0.121$. The orientation and WM load interaction was non-significant ($F = .527$, $p = .47$). The RTs for upright images during low and high concurrent load were, $M = 1865.75$, $SD = 681.50$ and $M = 1852.93$, $SD = 738.40$; and $M = 2045.81$, $SD = 919.87$ and $M = 1919.92$, $SD = 735.12$ for inverted images during low and high load respectively. A similar 2x2 ANOVA for the mean RTs revealed that both main effects and the interaction were non-significant ($F < 3.49$, $p > .068$ in all cases)

**Expression categorisation task**. The mean accuracy and RTs for correct face trials were computed for each individual and analysed in two 2x2 ANOVAs with Face Orientation (upright, inverted) and WM load (low, high) as within subjects factors. The RTs ANOVA revealed all main effects and the interaction were not significant, ($F < .3$, $p > .5$ in all cases).

The accuracy ANOVA revealed a main effect of Face Orientation, $F(1,45) = 32.908$, $p < .001$, $\eta^2 = 0.422$. Participants were less accurate when categorising expressions in inverted ($M = 68.57\%$, $SD = 13.00$) compared to upright faces ($M = 79.42\%$, $SD = 6.65$) thus replicating the face inversion effect.

The main effect of WM Load was not significant ($p = .70$, $F = .151$). However relevant to the research hypothesis the interaction between WM Load and Face Orientation was reliable, $F(1,45) = 34.120$, $p < .001$, $\eta^2 = .431$), indicating that WM load differentially affected the ability to categorise expressions depending on the orientation of the face (see Figure 3 and Table 1). As in Experiment 1, when responding to upright faces participants were more accurate when WM Load was low (*M*= 81.85%, *SD* = 7.62) compared to high (*M*= 77%, *SD* = 8.57). In contrast, for the inverted faces, participants' ability to correctly categorise expressions actually improved as WM load was increased from low (*M* = 65.76%, *SD* = 13.90) compared to high WM load (*M* = 71.37%, *SD* = 13.70).

Follow up pairwise comparisons confirmed that the detrimental effect of load when categorising upright faces ($t$ (45) = 3.545, $p$ < .001*, $d$ = 0.523, and the beneficial effect on expression categorisation when faces were inverted ($t$ (45) = 4.372, $p$ < .001, $d$ = 0.644 were both significant.

**Expression type analysis.** Similar to Experiment 1, further analysis, 2x2x6 ANOVAs, incorporating expression type (fear, disgust, sad surprise, anger, happy) (ten observations per expression type cell) as an additional factor were conducted to probe if categorisation of particular expressions were affected differentially by the other factors.

The main effect of Expression Type was significant $F$ (5, 225) = 113.810, $p$ <.001, $\eta^2$ = .717. Overall Happy stimuli were the easiest to categorise (93.1%), followed by surprise, sad, anger and disgust (83.7, 78.6, 73.4, and 72.8 respectively). The accuracy of correctly categorising fearful faces was by far the lowest; 43.4% (see Table 2).

The interaction between Expression and Orientation was also significant, $F$ (5, 225) = 6.256, $p$ <.001, $\eta^2$ = .122. For the upright faces the differential face categorisation accuracies mostly followed a similar pattern to that in Experiment 1 (Figure 2); happy faces were categorised most accurately, followed closely by surprise, anger, sad, disgust and finally fear.

The order of accuracy levels was the same for inverted faces, the only notable difference was that angry face categorisation was impacted substantially more by inversion (See Figure 2).

The three way interaction between Orientation, WM load and Expression Type was not significant ($F$ = 1.325, $p$ =.25), indicating that WM load did not differentially affect particular expressions at either orientation. The remaining effects were in line with the above detailed 2x2 ANOVA.

The equivalent RT ANOVA was conducted on correct trials data. For the RTs there was a main effect of expression type, $F(5, 180) = 44.564$, $p < .001$, $\eta^2 = 0.553$, and an expression by orientation interaction, $F(5, 180) = 3.017$, $p = .012$, $\eta^2 = 0.077$. For both these effects, the pattern closely followed that of the accuracy data, indicating an absence of speed-accuracy trade off (see Table 2). The remaining main effects, and interactions were not reliable for the RTs ($F < 3.1$, $p > .5$, in all cases).

**Discussion**

Categorisation rates for the six expressions in upright faces in Experiment 2 closely paralleled the pattern recorded in Experiment 1; happy and fear were categorised the most and least well respectively; the remaining expressions accuracy rates fell between these two. Categorisation accuracy of the six emotions also varied for the inverted faces and the pattern of accuracy levels was similar to upright faces. The only notable difference was that angry face categorisation was impacted substantially more by inversion. This pronounced impact of inversion for angry faces was also detected by Prkachin (2003). The authors suggest anger is accompanied with changes in the mouth and nose region that are shared with other emotions (sadness, fear and disgust). Scrutiny of the distinct feature; stare of the focused eyes, is required for correct categorisation of anger. Inversion may make distinctions based on this isolated feature harder which leads to the exaggerated impact of inversion for this emotion.

Orientation of the face had a substantial impact on expression categorisation accuracy. Participants were less accurate when categorising expressions in inverted compared to upright faces; thus the face inversion effect was replicated (Yin, 1969; Calder et al., 2000). The novel and pertinent finding was that, increased cognitive load did not detrimentally impact performance in all conditions, but rather the effect depended on whether the to-be processed face was upright or inverted. As in Experiment 1, for upright faces, accuracy of expression type judgments were lower in high compared to low load. In contrast, the ability to correctly categorise expressions improved with cognitive load when the presented face was inverted. The differential effect of cognitive load on categorising expressions as a function of face orientation is consistent with the cognitive load related dispersion of attentional window explanation. According to this notion, performance for upright faces is worse during high load as the attentional setting is dispersed away from the default optimal global setting in this situation. Whilst, categorisation of inverted faces actually improves when with cognitive load because the dispersed setting shifts processing from the local to more task appropriate global setting in this case.

Finally, as in Experiment 1, there was an absence of an expression by cognitive load interaction, indicating that cognitive load does not differentially affect categorisation of particular expressions in the current stimuli set. Reasons for this and alternative scenarios where an interaction may occur, together with the theoretical implications of the attentional window based explanation of the load effect are evaluated next.

## General Discussion

As reviewed in the introduction, numerous studies have uncovered an interactive effect between cognitive resources and affect processing. It is known that the neural response to passively viewed (Erk et al., 2007 and Van dillen et al., 2009) and actively attended affective stimuli (Blair et al., 2007), and the subjective experience of feelings (Kron et al., 2010) are all reduced in the presence of concurrent cognitive load. The current findings complement this body of literature and demonstrate that the ability to categorise expressions in upright faces is similarly hampered when cognitive resources are reduced.

We then employed both upright and inverted images to assess the mechanism of cognitive load's effect on expression categorisation. Whereas the efficiency of correctly categorising expressions in upright faces was reduced with load, the performance actually improved with load for inverted faces (see Figure 3). This differential effect of cognitive load is congruent with a cognitive load related dispersion in the attentional window (Ahmed & de Fockert 2012b; Marguc et al., 2011). It is known that upright and inverted faces solicit comparatively more holistic and local processing respectively (Yin, 1969; Calder et al., 2000). We propose that during upright face processing, the load-related dispersion in the attentional window causes an 'over globalisation' of the attentional window, expanding the setting away from the default optimal, resulting in the decreased expression categorisation. In contrast, for inverted faces, the dispersion shifts processing style from a local to a more task relevant holistic setting, improving expression categorisation in this case. Thus the current findings not only demonstrate expression categorisation is sensitive to cognitive load but go further by elucidating the underlying attentional mechanism inflicting the effects.

The current findings are compatible with the attentional explanation but is there alternative support that facial expression processing may be affected by changes in the attentional window? As far as we are aware cognitive load's effects on expression categorisation have not been examined from this prospective previously, however several alternative studies have found similar effects when the attentional window has been modulated by alternative means. For example, Martin et al. (2012) altered the attentional setting of participants by asking them to respond to local or global levels of Navon stimuli prior to performing an expression categorisation task. Comparable to the current findings, they found global priming reduced expression categorisation of upright faces. Whereas Weston and Perfect (2005) found altering the attentional setting via such priming methods similarly affects face identity recognition. Furthermore, Schmid, Bombari, Mast and Lobmaier (2011) found that the altered attentional settings associated with happy and sad moods, influence expression categorisation performance. Collectively such findings validate that expression categorisation is impacted when the attentional window settings are altered by priming or mood. The current studies add to this, by demonstrating a similar influence on expression categorisation when the attentional setting is modulated by imposed cognitive load.

Next we briefly reflect on the categorisation rates of the different expressions used. Categorisation accuracy levels are known to vary across the six basic facial expressions used (happy, sad, anger, fear, surprise and disgust) (e.g. Ekman et al., 1969). In the current experiments, happy stimuli were the easiest to categorise closely followed by anger, surprise, sad and disgust. Fearful faces were categorised the least accurately. The expression categorisation rates replicated previous patterns in comparable paradigms (e.g. Derntl et al., 2009; Prkachin, 2003). The novel aspect was assessing the interaction between cognitive load and specific expressions. Previous literature has demonstrated that experimental factors such as inversion and presentation time (Prkachin, 2003 and Derntl et al., 2009) have a differential impact on the six basic expressions, moreover evidence for the processing preference of particular expressions also exists (e.g. Fox et al., 2000). Thus the possibility of a differential influence of cognitive load on the different expression types was plausible. Although there were main effects of both expression type and WM load, the WM load by expression interaction was not significant, signifying that particular expressions are not differentially affected by cognitive load (see Table 2 & Figure 2). However it is important to acknowledge that the absence on this effect could be due to a Type II error. Whilst the repeated measures study was amply powered to detect the 2x2 effects (see footnotes 1&3) and included 60 observations per condition for these comparisons, the per condition observations were only ten for the by emotion type analysis. Whilst previous 6-AFC expression categorisation studies have based by emotion analysis ranging from 5 to 18 observations per emotion (e.g. Ekman et al., 1969; Philips et al., 2008; Derntl et al., 2009), recent guidelines suggest that observations less than 20 are not adequate to capture most behavioural effects (Simmons, Nelson, & Simonsohn, 2011). The study would thus need to be replicated with more observations at this level to claim with confidence that particular emotions are not differentially impacted by cognitive load availability.

**Theoretical Implications**

From a theoretical prospective the current findings affirm the robustness and generalisability of a load-related dispersion in the attentional window. The effect has previously been recorded using letter and word stimuli (Ahmed & de Fockert, 2012a; Ahmed & de Fockert, 2012b; Marguc et al., 2011). The current findings support that the cognitive load related shift from local to holistic settings also impacts environmentally more relevant facial expression stimuli in a similar manner. How these findings further our understating of facial expression categorisation is reflected on in this section.

LeDoux (1996) and Davidson and Irwin (1999) proposed that emotions are conscious experiences and thus must be represented in working memory. As such they are reliant on cognitive resources and therefore should be sensitive to limitations in these. This general view has been refined since to account for specific empirical findings. For example, Van Dillen and Koole (2007) explain cognitive load's attenuation effect on passively viewed valent stimuli in terms of a distraction effect; the distraction hypothesis. Whilst Kron et al. (2010) proposed the mere resource hypothesis, which explains that both conscious feelings and cognitive tasks draw on cognitive resources and thus the experience of feelings is diminished in the presence of cognitive load. The impact of cognitive limitations on immediate categorisation of facial expressions observed in the current study are in line with these general theoretical views but advance on these by proposing the attentional window based account as a more precise explanation of cognitive load's impact in this particular scenario of affect processing.

Categorising expressions is a three stage process. Firstly the perceptual information is processed, this is then interpreted as a particular expression, and finally a manual response mapping the interpretation to available options is made. Currently there is not a consensus on which stages are affected by cognitive load. Philips et al. (2008) found that cognitive load did not impact expression categorisation as a function of intensity of expressions. The authors interpreted this to indicate that the perceptual processing of expressions is not reliant on cognitive resources. Conversely, the authors found that expression categorisation ability decreases as number of response options to choose from are increased, evidencing that cognitive load affects the response selection stage of expression categorisation. However, even in the two category choice option the accuracy difference between no and dual conditions were substantial, implying that the number of response options alone cannot wholly account for the observed cognitive load effects. Moreover, Lynn et al. (2016), used a two label task, ‘angry’ and ‘not angry’, to assess the ability of individuals naturally varying in cognitive resources, high and low working memory capacity (WMC) participants, to correctly categorise the expressions. The low WMC individuals were worse at making correct categorisations even in the two option paradigm compared to individuals with greater cognitive resources i.e. high WMC individuals. Once more indicating that cognitive resources are required for a stage other than response selection.

In the current experiments load effects were found when the number of response options were kept consistent, and also opposing effects of load were found based on facial orientation – these effects are hard to consolidate with cognitive load solely affecting the label choice stage. Alternatively, they support that the perceptual stage of expression categorisations is sensitive to cognitive load.

But why might imposed cognitive load affect the perceptual processing stage in some scenarios (Lynn et al., 2016) but not others (Philips et al., 2008)? We consider that image presentation time may be an important determinant.  Within the expression categorisation literature presentation time is viewed as an indicator of cognitive effort required for processing, and images have been presented using a variety of timings, ranging from 33ms to 15seconds (see Derntl et al., 2009 for a review). Generally accuracy rates improve as presentation times are elongated, at least prior to celling effects taking effect. Philips et al. (2008) displayed faces for 3 seconds, whereas the presentation times in the current and Lynn et al.’s (2016) paradigm were comparatively much shorter (250ms and 500ms respectively). Thus the sensitivity of perceptual processing to cognitive load seems to be linked to presentation time – if ample time is provided perceptual processing is less affected by cognitive load, whereas during shorter more cognitively effortful presentations, cognitive load has a greater influence.

Collectively these findings support that cognitive load can impact expression categorisation at various stages; the current and Lynn et al.'s (2016) findings support an influence at the perceptual processing stage, whilst Philip et al.'s (2008) findings establish an impact at the later response selection stage. Investigations of individual differences in the perceptual and labelling stages of expression categorisations reveal that, at best performances on the two are only partially correlated (Croker & McDonald, 2005; Palermo, O'Connor, Davis, Irons, & McKone, 2013), indicating that the two processes are somewhat distinct. Future studies would need to incorporate factorial designs in which presentation time and number of response options are manipulated to tease apart the comparative impact cognitive load has on each sub-process of expression categorisation. Moreover given that everyday social encounters can require inferences of affective states during either sustained gaze or brief glances of facial expressions, further work exploring the interaction between presentation time and cognitive load is of both empirical and social importance.

**Limitations and Future Directions**

Although the controlled design used provided a clearer test of the effect that concurrent cognitive load has on basic expression categorisation it is important to acknowledge there are issues inherit in such paradigms, where a forced-choice response format is used to categorise static images supposedly conveying a single emotion (see Russell, 1994 and Nelson & Russell, 2013 for detailed discussions). Whilst reviewing all limitations associated with this paradigm is beyond the scope for the current research, it is important to reflect on paradigm limitations that are pertinent to the current studies, i.e. those that may be sensitive to cognitive load.

In the current study we used easily recognisable expression images of young Caucasian adults from the NimStim database (Tottenham et al., 2009). Whilst cognitive load did significantly reduce categorisation accuracies, overall people were relatively apt at categorising expressions, with mean accuracy rates in the high 70s for the upright images (see Table 1). Evidence suggests that less recognisable and ambiguous expressions are more effortful to categorise. For example, Orgeta and Philips (2007) found elderly, compared to young individuals, were worse at recognising certain low intensity emotions, which may be partially due to age related cognitive decline. And Neta, Norris and Whalen (2009) found ambiguous expressions took longer to respond to, denoting a potentially greater draw on cognitive resources compared to easily recognisable ones. Since most everyday interactions are based on subtler low intensity expressions (Motley & Camden, 1988; Hess, Blairy & Kleck, 1997), the impact of externally imposed cognitive limitations on lower intensity and more ambiguous expression processing may well be more substantial and would be an aspect worthy of future investigations.

Another factor which may interact with cognitive load's impact on expression categorisation is the ethnic familiarity of the presented faces. It is well established that we do worse at processing expressions and identity of faces from ethnically unfamiliar compared to familiar ones, the so-called in-group advantage effect (Elfenbein, & Ambady, 2002). This hindered performance for unfamiliar ethnicity faces implies this process is more demanding for us and may well be one that requires comparatively more cognitive resources. In the current experiments all images were of Caucasian models, whereas the participant sample included both Caucasian and non-Caucasian ethnicities (South London students). The ethnicity analysis (see footnote 2) revealed that both ethnicity groups categorised expressions in the Caucasian images equally well. The absence of the in-group advantage effect is most likely due to the high familiarity to different ethnicities in this sample (Elfenbein & Ambady, 2003; Biehl et al., 1997). The experiment would need to be replicated with participants from less ethnically diverse populations to assess potential effects between cognitive load and image ethnicity familiarity (e.g. Matsumoto; 1990).

Finally we would like to take a step back and consider how the current findings aid understanding of affect processing in broader terms. Here we adopted a local single channel approach to consider how concurrent load influenced visual facial expression categorisation. A cognitive-attentional account was employed to explain the observed effects. However, the utility of a single channel approach such as this can have limitations (see Hall, Schmid Mast, 2007). For example, information relating to a person's affective state is not extracted from a single channel such as the visual facial expression in isolation, but rather other avenues of information such as body language and contextual information can influence our judgements (e.g. Righart & de Gelder, 2008; Willis, Palermo, & Burke, 2011).

Moreover as reviewed in the introduction, expression categorisation has been investigated from both local and distal perspectives. Distal factors such as societal influences and personality differences are also known to influence expression categorisation (e.g. Said, Haxby & Todorov, 2011; Nowicki & Duke, 1994; Hall, Andrzejewski &Yopchick, 2009).

Thus whilst the current research demonstrates that expression categorisation is indeed sensitive to cognitive load and provides a novel cognitive-attentional based explanation for the impact, it is important to acknowledge that a more integrative approach taking account of both personality as well as cognitive factors, and employing multi-channel designs are required to gain a more comprehensive understanding of how and why we respond to facial expressions the way we do.

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