UNIVERSITY of CALIFORNIA PRESS | Collabra

Schietecat, A. C., et al. (2018). Predicting Context-Dependent Cross-Modal Associations with Dimension-Specific Polarity Attributions Part 1 – Brightness and Aggression. *Collabra: Psychology,* 4(1): 14. DOI: https://doi.org/10.1525/collabra.110

ORIGINAL RESEARCH REPORT

Predicting Context-Dependent Cross-Modal Associations with Dimension-Specific Polarity Attributions Part 1 – Brightness and Aggression

Anne C. Schietecat, Daniël Lakens, Wijnand A. IJsselsteijn and Yvonne A. W. de Kort

Although researchers have repeatedly shown that the meaning of the same concept can vary across different contexts, it has proven difficult to predict when people will assign which meaning to a concept, and which associations will be activated by a concept. Building on the affective theory of meaning (Osgood, Suci, & Tannenbaum, 1957) and the polarity correspondence principle (Proctor & Cho, 2006), we propose the dimension-specificity hypothesis with the aim to understand and predict the context-dependency of cross-modal associations. We present three sets of experiments in which we use the dimension-specificity hypothesis to predict the cross-modal associations that should emerge between aggression-related concepts and saturation and brightness. The dimension-specificity hypothesis predicts that cross-modal associations emerge depending upon which affective dimension of meaning (i.e., the evaluation, activity, or potency dimension) is most salient in a specific context. The salience of dimensions of meaning is assumed to depend upon the relative conceptual distances between bipolar opposed concept pairs (e.g., good vs. bad). The dimension-specificity hypothesis proposes that plus and minus polarities will be attributed to the bipolar concepts, and associations between concrete and affective abstract concepts that share plus or minus polarities will become activated. Our data support the emergence of dimension-specific polarity attributions. We discuss the potential of dimension-specific polarity attributions to understand and predict how the context influences the emergence of cross-modal associations.

Keywords: cross-modal associations; context-effects; affective dimensions of meaning; color; brightness

> "It is clear that everything on this planet is relative and has independent existence only insofar as it is distinguished in its relations to and from other things… since every conception is thus the twin of its opposite, how could it be thought of first, how could it be communicated to others who tried to think of it, except by being measured against its opposite?" Abel (as cited in Freud, Collected Papers, Strachey edn, IV, p. 187)

Understanding how we give meaning to concepts lies at the core of being able to predict how people behave, think and feel. Studies in cognitive psychology, social cognition, and linguistics convincingly show that task-specific contexts play a crucial role when constructing meaning and when engaging in conceptual thought (e.g., Barrett, Wilson-Mendenhall, & Barsalou, 2014; Elliot & Maier, 2012; Gawronski, Ye, Rydell, & De Houwer, 2014; Mitchell, Nosek, & Banaji, 2003; Paradis & Willners, 2011; Rothermund & Wentura, 2001, 2004; Schwarz, 2007; Smith, 1996). Although researchers have repeatedly shown that the meaning of the same concept can vary across different contexts, it has proven difficult to predict when people assign *which* meaning to a concept. Incorporating context effects in models of human cognition is one of the major future challenges in psychological research (e.g., Mesquita, Feldmann Barrett, & Smith, 2010).

An impressive number of studies indicate that features present in a specific context can influence the associative meaning of a concept in a task (e.g., Blair, 2002; Elliot & Maier, 2014; Frühholz, Trautmann-Lengsfeld, & Herrmann, 2011; Lakens, Fockenberg, Lemmens, Ham, & Midden, 2013). For example, studies show that in an achievement context, red is associated with failure and negativity (e.g., Moller, Elliot, & Maier, 2009), while in a romantic context, red is associated with attraction and excitement (e.g., Elliot & Pazda, 2012). Although context-effects have repeatedly been demonstrated, it remains difficult to predict when specific context features will influence the meaning of concepts.

Concepts can be defined as knowledge about the world, consisting of general attributes (e.g., positive-negative), specific exemplars, and individual features (see Greenwald

Eindhoven University of Technology, NL

Corresponding author: Anne C. Schietecat (A.C.Schietecat@tue.nl)

et al., 2002). Concepts are related to each other through associations, which differ in strength. The stronger the association, the more strongly one concept activates another. Concepts, hence, can become activated to a different degree. In the current manuscript, we refer to the meaning of concepts as points in a multidimensional space (e.g., Nosofsky, 1986), where the distance between points reflects the relation between concepts. More specifically, similarity between concepts decreases exponentially as a function of the distance (Shepard, 1987), in such a way that concepts are perceived as more similar, when they are closer rather than distant in the multidimensional space. Central to this multidimensional approach to conceptual space is the idea of polar opposition: Concepts can be expressed in terms of more or less of multiple underlying *bipolar* dimensions in a multi-dimensional space (e.g., good-bad, active-passive, see Kruschke, 1992; Osgood, Suci, & Tannenbaum, 1957). One way in which associations between concepts emerge is when both are attributed 'more' or 'less' of the bipolar dimension (e.g., Osgood et al., 1957).

We are particularly interested in how context influences associations between concrete and affective abstract concepts, which we refer to as cross-modal associations. In the field of perception, cross-modal associations (or cross-modal correspondences) are referred to as associations between concepts or features from different sensory modalities (e.g., brightness and sound, see Spence, 2011 for a review). However, the term cross-modal associations has also been used more generally to define associations between various modalities, be it less frequently (e.g., between color and emotion or language, see for example Dael, Perseguers, Marchand, Antonietti, & Mohr, 2016; Elliott, Cowan, & Valle-Inclan, 1998; Gardner, 1974; Hanauer & Brooks, 2003; Hupka, Zaleski, Otto, Reidl, & Tarabrina, 1997; Lakens, Semin, & Garrido, 2011). In the current manuscript, we will use the term cross-modal association to indicate associations between a concrete and an affective abstract concept pair (e.g., black and white with aggressive and calm) based on an underlying conceptual dimension (e.g., valence).[1] We acknowledge that this definition deviates from the more common definition used in the field of perception.

Based on factor analyses performed on a large amount of cross-cultural data, the research by Osgood et al. (1957) revealed that people can structure concrete and affective abstract concepts along (at least) three main dimensions, namely evaluation, activity and potency. Based on this seminal work by Osgood and colleagues, we propose the *dimension-specificity hypothesis*, which is the idea that context-dependent cross-modal associations can be predicted by understanding which dimension of meaning becomes most salient in a specific context. The dimension-specificity hypothesis predicts that the direction and strength of cross-modal associations between the same pairs of bipolar concepts (e.g., bright vs dark, and aggressive vs calm) can depend crucially on the specific dimension of meaning that is most salient in a specific context.

We tested the dimension-specificity hypothesis across 3 sets of studies. We first investigated whether the dimension-specificity hypothesis allowed us to predict context-dependent associations between brightness, saturation, and aggression. We then used the dimension-specificity hypothesis to explain previously observed context-effects between brightness and valence or activity (Experiment 2), and in Experiment 3, we tested a more subtle prediction of the dimension-specificity hypothesis that examined how categorization labels of the task influence salience of dimensions of meaning. Before we present the dimension-specificity hypothesis in more detail, we first review theories on which the dimension-specificity hypothesis is built, including the affective theory of meaning (Osgood et al., 1957) and the polarity correspondence principle (Proctor & Cho, 2006; Proctor & Xiong, 2015).

Dimensions of meaning

As outlined above, concepts are related to each other through associations, which differ in strength. The stronger the association, the more strongly one concept activates another (Greenwald et al., 2002). Although very similar concepts can be strongly associated in a knowledge network, so can extremely dissimilar concepts. As an important example, bipolar opposed concepts such as black and white are on opposite endpoints of at least one dimension in a multidimensional space, but free association tasks show that bipolar concepts are strongly associated (e.g., Jenkins, 1970; Paradis & Willners, 2011). Bipolar concepts are strongly associated through their 'relation by contrast' (Murphy, 2003), and play an important role in activating salient dimensions that structure knowledge networks (Greenwald et al., 2002).

Although Osgood et al. (1957) emphasize that there are many dimensions that structure meaning, the results of their extensive research program have repeatedly shown that people use three primary dimensions when assigning (affective) meaning to concepts: The evaluation dimension (e.g., goodness, pleasantness, or beauty), the activity dimension (e.g., quickness, agitation, or warmth), and the potency dimension (e.g., roughness, masculinity, or weight). The three dimensions each span a continuum from less to more (e.g., immoral to moral, Osgood & Richards, 1973). Osgood and colleagues (1957, p. 72) propose that the meaning of concepts can vary multi-dimensionally. In other words, the variance along one dimension can be independent of the variation along another dimension. Therefore, concepts might be for example judged as good and strong (e.g., hero), but also as good and weak (e.g., pacifist). Importantly, Osgood and colleagues stress that these dimensions are not exhaustive, and the composition can change as a function of the context (e.g., dimensions can collapse into one dimension dependent on the evaluated concepts, see Osgood et al., 1957, p. 74).

In their affective theory of meaning, Osgood and Richards (1973) proposed three basic characteristics of human cognitive processes that explain how concepts become associated in their affective theory of meaning, namely, bipolar organization of dimensions of meaning, polarity attribution, and parallel polarity. From the mid-twentieth century, these basic cognitive principles have been prominent in many other lines of research on cross-modal associations specifically, and on associations more generally. We discuss each of these three basic characteristics below.

Bipolar organization, polarity attribution, and parallel polarity

Osgood and Richards (1973) start with the proposition that conceptual dimensions are represented as bipolar oppositions. An impressive number of theories in cognitive psychology and linguistics support the idea that polar opposition is a crucial part of conceptual thought (e.g., Banks, Clark, & Lucy, 1975; Greenwald et al., 2002; Holmes & Lourenco, 2011; Kornblum & Lee, 1995; Kruschke, 1992; Medin & Schaffer, 1978; Murphy, 1996; Osgood & Richards, 1973; Paradis & Willners, 2011; Proctor & Cho, 2006; Proctor & Xiong, 2015; Walsh, 2003).

A second important aspect of the affective theory of meaning as defined by Osgood and Richards (1973) is that people attribute positive polarity to one of the polar opposites, and negative polarity to the opposite pole. Good, active, and strong are all 'more' of the evaluation, activity, and potency dimensions, respectively, and thus typically form the plus pole of the scale, while bad, passive, and weak all have 'less' of the respective dimensions, and thus typically form the minus pole of the scale. This idea, that is central to the dimension-specificity hypothesis, is similar to, but more specific than the theoretical idea of a single magnitude dimension underlying cross-modal associations (e.g., Walsh, 2003), in that concepts can be 'more' or 'less' on specific dimensions (e.g., evaluation, activity, or potency).

The third process contributing to the emergence of associations between concepts according to Osgood and Richards (1973) is the notion of parallel polarity. Parallel polarity, or the polarity correspondence principle (Proctor & Cho, 2006), predicts that endpoints of dimensions will be related in parallel, plus poles with plus poles, and minus poles with minus poles. For example, when the opposition between good and bad and the opposition between strong and weak become aligned, based on their plus polar attributions, good and strong will be associated, while based on their minus polar attributions, bad and weak will be associated.

Studies show that non-evaluative dimensions such as salience (e.g., Proctor & Cho, 2006; Rothermund & Wentura, 2004), perceptual dimensions such as intensity or magnitude, as well as conceptual amodal dimensions (e.g., Marks, 1978; Spence, 2011; L. Walker & P. Walker, 2016) and affective dimensions (e.g., Collier, 1996) can underlie polarity correspondence. For example, bright light and loud sounds are both perceived as being 'more' of an intensity dimension compared to dim light and soft sounds, and might therefore be associated (Marks, 1978). In the current manuscript, we aim to show that polarity correspondence on specific dimensions of meaning (i.e., evaluation, activity, or potency dimension) might predict context-dependent cross-modal associations between concrete and affective abstract concepts.

Current theories about polarity correspondence suggest that concepts are associated when they both form the plus pole or minus pole on any dimension (e.g., Proctor & Xiong, 2015). However, as outlined above, concepts are represented in a multidimensional space, and consequently, each concept is represented along multiple conceptual dimensions. It is therefore possible that a concept forms the plus pole on one dimension, but the minus pole on another dimension. In the current set of studies, we focus on the concept of aggression, which compared to calmness forms the *plus* pole on the activity dimension, but the *minus* pole on the evaluation dimension (Russell & Mehrabian, 1977). Brightness is more active, and more positive, compared darkness, and thus forms the plus pole on both the activity and the evaluation dimension, whereas darkness forms the minus pole on the activity and evaluation dimension (e.g., Adams & Osgood, 1973; Lakens et al., 2013; Marks, 1978; Mattes, Leuthold, & Ulrich, 2002; Meier, Fetterman, & Robinson, 2015). If polarity correspondence is indeed a mechanism in cross-modal associations, it is essential to predict along which specific dimension aggression-calmness becomes aligned with a second pair of concepts. Following the principle of parallel polarity, aggression could be associated with brightness (when aggression is attributed the plus pole on the activity dimension), but also with darkness (when aggression is attributed the minus pole on the evaluation dimension). Thus, it seems likely that the polarity correspondence that emerges will be context-dependent, and is determined by the salience of either the evaluation dimension or the activity dimension. When the activity dimension is salient, cross-modal associations between aggression and brightness, and between calmness and darkness would be predicted. However, if the evaluation dimension is salient, cross-modal associations between aggression and darkness, and between calmness and brightness would be predicted.

Importantly, in the current manuscript, we assume that associations between concrete and affective abstract concepts depend on their context-dependent relation to other concepts (e.g., brightness as compared to darkness), in line with other studies investigating cross-modal associations (e.g., Lakens et al., 2012; L. Walker & P. Walker, 2016). Whether associations emerge automatically, or dependent on context-specific factors is under debate (see for example, Spence & Deroy, 2013), but as far as the dimension-specificity hypothesis predicts they can be both. **Figure 1** provides a schematic illustration of a two-dimensional conceptual space with the concepts aggression, calmness, brightness, and darkness.

Dimension specificity hypothesis

To predict context-dependent cross-modal associations between concrete and affective abstract concepts, we propose the *dimension-specificity hypothesis*, which is based on the idea that context-dependent cross-modal associations can be predicted by understanding which dimensions of meaning (i.e., the evaluation, activity, or potency dimension) become most salient in a specific context. The direction and strength of cross-modal associations between the same bipolar concept pairs (e.g., bright vs dark, and aggressive vs calm) depend on the specific dimension of meaning that is most salient in

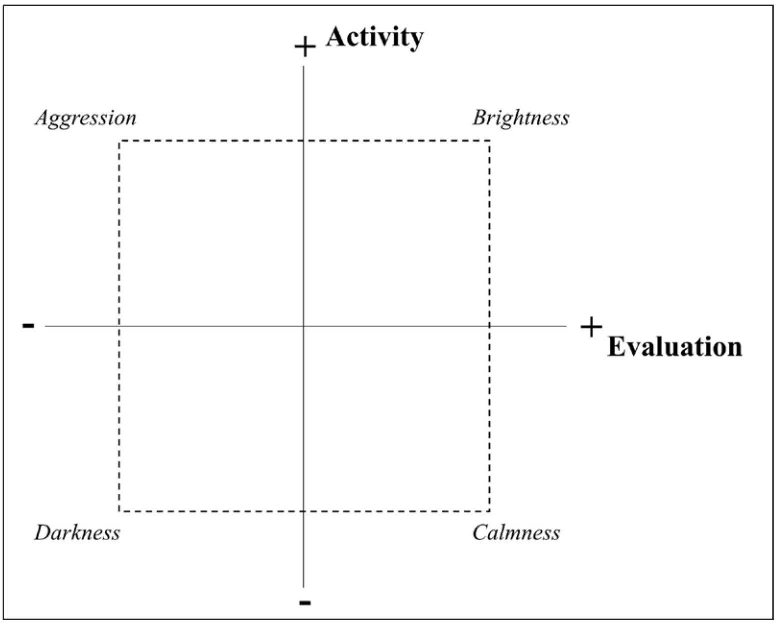

Figure 1: Schematic illustration of the concepts aggression, calmness, brightness, aggression in a two-dimensional space consisting of the activity and evaluation dimension. When the activity dimension (vertical) is salient, aggression and brightness (the two top concepts), and calmness and darkness (the two bottom concepts) will become associated. However, when the evaluation dimension (horizontal) is salient, aggression and darkness (the two left concepts) and calmness and brightness (the two right concepts) will become associated.

a specific context. If the dimension-specificity hypothesis holds, we should be able to predict cross-modal associations in situations where concepts are attributed positive and negative polarity on multiple dimensions, and thus where parallel polarity could be resolved in multiple ways (e.g., aggressive vs calm and bright vs dark). Which dimensions of meaning become activated within a task depends on the context.

How does the context activate specific dimensions of meaning? Based on literature on this topic, we assume that polar oppositions activate the dimension they are opposed on (Becker, 1980; Lakens, 2012; Lakens, Semin, & Foroni, 2012; Paradis & Willners, 2011; Scherer & Lambert, 2009; Willners & Paradis, 2010). For example, studies of antonymy in the field of linguistics suggest that concept pairs in an antonym relationship (e.g., good vs bad) evoke properties of the same underlying dimension (e.g., goodness; Paradis & Willners, 2011; Paradis, van de Weijer, Willners, & Lindgren, 2012). We see a similar tentative assumption that dimensions can become activated through bipolar oppositions in a task in experimental research in social cognition. For example, Moors, Spruyt, and de Houwer (2010, p. 29) note that “The mere fact for example that all stimuli in a prototypical affective priming study have a polarized valence might be sufficient to increase the salience of valence (see also Moors, 2007; Moors & de Houwer, 2006; Spruyt, Teige-Mocigemba, Everaert & Klauer, 2008)”. In the current manuscript, we aim to explicitly test this assumption. We expect that when a concept *pair* (i.e., bipolar opposed concepts) is present in a cognitive task, the dimension(s) on which the bipolar opposed concepts differ most will become salient. These conceptual distances thus reflect the extent to which bipolar concepts differ in terms of evaluation, activity, and potency. For example, when people process the concepts ‘fast’ and ‘slow’, which are highly opposed on the activity dimension, but less strongly opposed on for example the evaluation dimension (Osgood et al., 1957), the activity dimension will become salient, and will receive more attention than other dimensions of meaning.

In cognitive tasks in psychology (e.g., an affective priming paradigm), multiple bipolar concept pairs are often present. Therefore, multiple dimensions can potentially become activated in such a task context. The dimension-specificity hypothesis predicts that polarity attribution will be based on the salient dimension. We propose that a weighting process will determine which of the activated dimensions becomes most salient in the task specific context. For example, when categorizing black, white, positive, and negative related stimuli in a cognitive task, both concept pairs (i.e., black vs white, and positive vs negative) have the highest conceptual distance on the evaluation dimension, which will therefore receive the most (relative) weight, and thus will become the salient dimension of meaning that structures cross-modal associations in this context. We expect that when the weight of the salient dimension in a specific task is relatively high, a stronger association will emerge between concept-pairs than when the weight of the salient dimension is relatively low. See **Figure 2** for an illustration of the proposed process to predict context-dependent cross-modal associations with the dimension-specific polarity attributions.

Current research

To test the dimension-specificity hypothesis, we conducted three series of experiments, in which we predicted the emergence of associations between concrete stimuli (i.e., color related or light related) and affective abstract

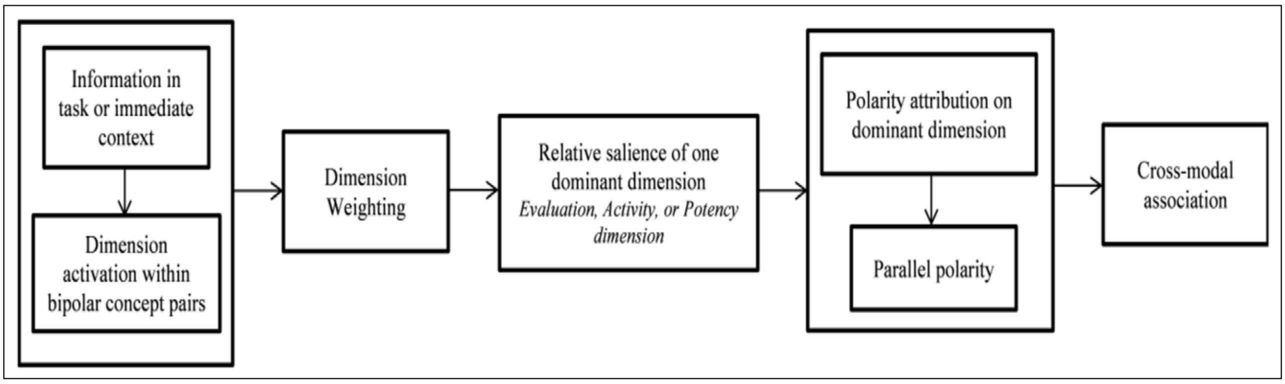

Figure 2: An illustration of the process to predict context-dependent cross-modal associations with dimension-specific polarity attributions.

stimuli (i.e., aggression related). For each set of studies, we determined the conceptual distances of concept-pairs relevant for the task (i.e., categories and stimuli) based on pilot studies or findings in the literature. Next, we predicted which dimension would become salient in the task. In the current set of experiments, we focused on the evaluation and activity dimension. Subsequently, the polarities of the concepts for the salient dimension were identified, and we examined whether the associations between concepts predicted by the dimension-specificity hypothesis would emerge. We tested the dimension-specificity hypothesis by manipulating the context, either by manipulating the opposing stimuli (Experiment 1), manipulating the presentation of the stimuli (i.e., brightness presented on the screen or with a light fixture, Experiment 2), or by manipulating the labels in the task (Experiment 3).

Implicit association test

In order to test the dimension-specificity hypothesis, we use the implicit association test (IAT, Greenwald, McGhee, & Schwartz, 1998). In an implicit association test, stimuli belonging to two concept pairs (i.e., black-white figures, positive-negative words) have to be categorized into combined categories (e.g., black-negative, white-positive) by left or right keypresses. It is typically observed that when people have to press the same key for strongly associated concepts, the categorizations are faster, and response times are lower, compared to when people have to press the same key for concepts that are weakly or not associated.

The IAT was developed to measure associations in knowledge structures consisting of bipolar concept pairs such as female-male, and positive-negative (Greenwald et al., 2002). Multiple underlying processes of the IAT have been identified (for an overview, see Teige-Mocigemba, Klauer, & Sherman, 2010). The IAT can measure the strength of pre-existing associations between concepts (Greenwald et al., 2002), but is also influenced by task-dependent factors. For example, asymmetries in the salience of the target and attribute categories can determine the associations that will emerge within a specific task context, resulting in associations without any intrinsic meaning (Rothermund & Wentura, 2004).

We used the IAT because it contains, by default, multiple concept pairs consisting of polar opposites, making it ideally suited to examine the context dependency of cross-modal associations. The IAT has been used in previous studies to measure cross-modal associations between two sensory modalities, for example between taste and pitch (Crisinel & Spence, 2009), between odor and color (Demattè, Sanabria, & Spence, 2007), and between visual and auditory stimuli (Parise & Spence, 2012). Furthermore, the task provides the possibility to systematically manipulate the context (e.g., by adjusting category labels). Lastly, the model of knowledge structures proposed to underlie associations in the IAT (Greenwald et al., 2002) shows important conceptual similarities to multi-dimensional models of meaning that we use here to derive our theoretical predictions. To date, there is no consensus about the extent to which IAT effects are the result of pre-existing attitudes or task-dependent salience asymmetries (see, for example, De Houwer, Teige-Mocigemba, Spruyt, & Moors, 2009; Greenwald, Nosek, Banaji, & Klauer, 2005; Proctor & Cho, 2006; Rothermund, Wentura, & De Houwer, 2005). In the set of studies we report here, we only use the IAT to show the context-dependency of cross-modal associations. As far as the dimension-specificity hypothesis is concerned, context-dependent associations can be either pre-existing, or emerge due to task dependent factors.

Sample size justification and statistical analysis

The sample sizes for Experiments 2 and 3 were determined a priori based on a target of .9 power with at least medium effect sizes expected, using statistical power analysis (G*Power; Faul, Erdfelder, Lang, & Buchner, 2007). Experiment 1 was part of an educational course, and there the sample consisted of all the students participating in the course. In addition, the design and procedure of Experiments 2 and 3 were approved a priori by the ethical board of the human-technology department of Eindhoven University of Technology.

In all experiments, extreme fast and slow responses were removed by excluding values that were 1.5 times the interquartile range above the 3th quartile, or 1.5 times the interquartile range below the 2nd quartile within participants (Tukey, 1977). The outliers and errors are reported (in percentages) for each experiment in the results section. For each study, we report frequentist and

Bayesian statistics, confidence intervals around Hedges' *g* based on d_{av}, and the Bayes Factor (JZS) with a r-scale of .707 (Rouder, Speckman, Sun, Morey, & Iverson, 2009). For completeness, we report the robust statistics using the Yuen-Welch method for comparing 20% trimmed means (Wilcox, 2012; Wilcox & Tian, 2011) in the supplementary materials (see Appendix C in the supplementary materials for the robust statistics).

Experiment 1

In the current experiment we aimed to make predictions about the associations between brightness, saturation, and aggression with two implicit association tests. The brightness and saturation of colors has been shown to be strongly associated with the evaluation, activity, and potency dimensions (EAP-dimensions) and primarily with the evaluation and activity dimensions respectively (Valdez & Mehrabian, 1994). In the current experiment, we manipulated the salient dimension within a task by adjusting the concrete color features (i.e., brightness or saturation), but kept the affective abstract concepts (aggression and calmness) constant across the two IATs. This allowed us to examine whether a similar color stimulus that differed in saturation or brightness would be associated with aggression in one task, and calmness in another task, dependent on whether evaluation or activity was the salient dimension. Whereas we expected the evaluation dimension to become salient in Experiment 1A where brightness was manipulated, we expected the activity dimension to become salient in Experiment 1B where saturation was manipulated.

Experiment 1A: bright-dark versus aggressive-calm

In Experiment 1A, we tested the associations between bright and dark purple, and aggression and calmness related concepts. The brightness of colors is shown to be most strongly associated with the evaluation dimension (Valdez & Mehrabian, 1994). Brighter colors as opposed to darker colors are perceived as more positive than active (Adams & Osgood, 1973; Valdez & Mehrabian, 1994). Based on these findings, we estimated the distance of the concept pair bright-dark (as presented in the color stimuli and target labels) to be the highest on the evaluation dimension. Aggression as opposed to calmness (as presented in stimulus words and attribute labels) was expected to activate both the evaluation and activity dimension, as aggression-calmness is conceptually distant on the activity as well as the evaluation dimension (Russell & Mehrabian, 1977; pilot Study 2, see Appendix B in the supplementary materials for the results). Weighting the dimension distances of all the concept-pairs, we expected the evaluation dimension to become salient in Experiment 1A. Brightness and calmness were predicted to form the plus pole on the evaluation dimension, whereas darkness and aggression would form the minus pole on the evaluation dimension. As a result, brightness and calmness (and darkness and aggression) should become associated in Experiment 1A.

Method

Participants

Twenty-one participants at Eindhoven University of Technology, all students of the first-year course Psychology and Technology, volunteered to participate for partial course credits.

Materials

Participants were asked to categorize calm (i.e., *zen, calm, relaxed, peaceful*) and aggressive (i.e., *furious, murder, enraged, destroy*) words, and dark and bright stimuli into the categories aggressive, calm, brighter ('helderder' in Dutch), and darker ('donkerder' in Dutch). The figures consisted of relatively bright (RGB: 191, 115, 230; xyY: .28, .19, 32.58) and relatively dark purple (RGB: 64, 38, 77; xyY: .26, .17, 3.29)[2] squares. The colors were chosen in Adobe Photoshop C6 (in standard RGB color space).

Design

The IAT consisted of practice blocks and two critical experimental blocks, where the brightness vs darkness and aggressive vs calm pairings of the response keys were manipulated. In one block, dark figures and aggressive words shared a response key (and bright figures and calm words shared the other response key), whereas in the other block dark figures and calm words shared a response key (and bright figures and aggressive words shared the other response key). The order of the experimental blocks, as well as the response key assignment (whether black figures were assigned to the left or right response key) was counterbalanced between participants.

Procedure

Participants completed the implicit association task at home. They were instructed to perform a categorization task where they would have to categorize words and figures. Following the typical procedure in the IAT, participants first received two practice blocks, one with the figures and the dark-bright categorization task, and one with the word stimuli and the aggressive-calm categorization task. The practice blocks consisted each of 20 trials, in which stimuli were randomly presented. In a third block, words and figures had to be categorized simultaneously. This block consisted of a total of 60 trials, in which 30 word stimuli and 30 figure stimuli were randomly presented. In a fourth block, participants received a practice block with 40 trials to learn the inverted response assignments for the figure stimuli. In the last block, a combined classification task of 60 trials was presented, in which responding was inverted for one category compared to block three.

The presentation of the stimuli and registration of the responses were controlled by Inquisit software. All word stimuli were presented in black uppercase letters in the middle of a grey (RGB: 128, 128, 128) computer screen. Category labels (dark, bright, aggressive, calm) were shown at the top right and top left corners of the display, referring to the assignment of the categories to responses. Two keys on a QWERTY keyboard were used as response keys (A: left, L: right). In each trial, the stimulus remained on the screen until a response was registered. When participants entered an incorrect response, the stimulus remained on the screen, and an error message was displayed in red beneath the stimulus ("ERROR"). The intertrial interval was 250 milliseconds.

Results

Erroneous responses (6%) and extremely fast and slow responses (6%) were excluded from analysis. We calculated the mean response times in milliseconds for each participant for the two critical blocks. As expected, response latencies were shorter when the categories brighter and calm, and darker and aggressive shared the same response keys (M = 575 ms, SD = 74 ms) than when brighter and aggressive, and darker and calm shared the same response keys (M = 791 ms, SD = 161 ms), 95% CI = [–278.29, –153.65], JZS BF_{10} = 31674.37, $t(20) = 7.23$, $p < .001$, Hedges' g = 1.66, 95% CI = [–2.42, –1.01]. These results support the idea that a cross-modal association emerged between brightness and calmness, and darkness and aggression. Whereas in Experiment 1A we tested whether dark and bright purple colored stimuli were associated with the evaluation dimension, in Experiment 1B we tested whether saturated as opposed to unsaturated purple colored stimuli activated the activity dimension.

Experiment 1B: saturated-unsaturated versus aggressive-calm

In Experiment 1B, we tested the associations between saturated and unsaturated purple, and aggression and calmness related concepts. Based on the results of Valdez and Mehrabian (1996), we expected that the saturated-unsaturated concept pair (as presented in the color stimuli and target labels) would have a higher conceptual distance on the activity dimension than on the evaluation dimension. As before, the concept pair aggression-calmness (as presented in stimulus words and attribute labels) was still assumed to differ equally on the activity and evaluation dimension. Overall, the activity dimension should receive the highest weight, and thus was predicted to become salient. Saturated stimuli and concepts related to aggression were would form the plus pole on the activity dimension, whereas unsaturated stimuli and calmness related concepts would form the minus pole on the activity dimension. Based on these polarity attributions, saturated and aggression, and unsaturated and calmness should be associated in the IAT. We conducted two versions of the saturation IAT. In Version 1, the saturated stimuli were darker than the bright stimuli used in Experiment 1A. To investigate whether a same stimulus with high saturation and high brightness can be associated with aggression in an activity context (i.e., compared to an unsaturated stimulus), and with calmness in an evaluation context (i.e., compared to a darker stimulus), we conducted a replication study (Version 2) in which the saturated stimuli were exactly identical to the brighter stimuli used in Experiment 1A. We report the results of Version 1 (and add the results of Version 2 in brackets).

Method

Participants

Twenty-eight participants (Version 2: forty-five participants) who did not participate in other experiments reported here, all students of the first-year course Psychology and Technology at Eindhoven University of Technology, volunteered for partial course credits.

Design and Procedure

Participants were asked to categorize calm and aggressive words, and saturated and less saturated colored stimuli into the categories aggressive, calm, saturated, and unsaturated. The same calm and aggressive words as in Experiment 1A were used. The figures consisted of relatively saturated (RGB: 87, 12, 128; xyY: .24, .11, 4.72) and relatively unsaturated (RGB: 114, 89, 128; xyY: .28, .22, 12.69)[2] purple squares. In Version 2, the figures consisted of relatively saturated (i.e., exactly the same as in Experiment 1A; RGB: 191, 115, 230; xyY: .28, .19, 32.58) and relatively unsaturated (RGB: 165, 143, 175; xyY: 0.29, 0.26, 45.06) purple squares. The design and procedure were identical to Experiment 1A.

Results

Erroneous responses (9%; 8% Version 2) and extremely fast and slow responses (6%; 6% Version 2) were excluded from analysis. We calculated the mean response times in milliseconds for each participant for the two critical blocks. As expected, response latencies were shorter when the categories saturated and aggressive, and unsaturated and calm shared the same response key (M = 564 ms, SD = 70 ms; Version 2: M = 610 ms, SD = 167 ms), than when saturated and calm, and unsaturated and aggressive (M = 802 ms, SD = 161 ms; Version 2: M = 744 ms, SD = 170 ms) shared the same key, 95% CI [182.96, 293.43], JZS BF_{10} = 6387558.02, $t(27) = 8.85$, $p < .001$, Hedges' g = 1.87, 95% CI [1.25, 2.58] (Version 2: 95% CI [80.87; 188.01], JZS BF_{10} = 2304.87, $t(44) = 5.06$, $p < .001$, Hedges' g = .78, 95% CI [.44; 1.14]). These results support the idea that a cross-modal association emerged between saturated and aggression, and unsaturated and calmness. See **Figure 3** for the mean reaction times for the critical blocks of the IATs of Experiment 1 (Version 1 of Experiment 1B).

Discussion

These results provide further support for the dimension-specificity hypothesis. When stimuli differed in terms of their brightness (Experiment 1A), brighter and darker color stimuli were categorized based on the evaluation dimension. Darker colors, as compared to brighter colors, were associated with aggression. However, when stimuli differed in terms of their saturation (Experiment 1B), saturated colors were associated with aggression, and unsaturated colors with calmness. As saturated and unsaturated colors do not differ in terms of valence, these results suggest that the associations emerged based on the activity dimension. Therefore, the same stimulus with

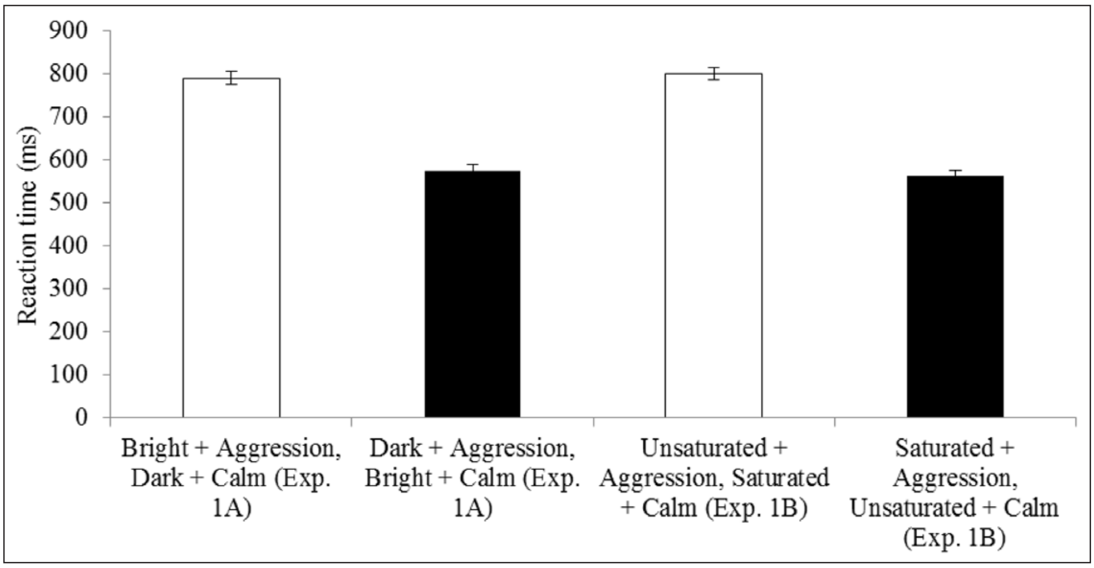

Figure 3: Mean reaction times in milliseconds for the critical blocks of the brightness IAT of Experiment 1A (left) and the saturation IAT of Experiment 1B (right). Error bars represent standard errors of the mean.

high saturation and high brightness can be associated with aggression in an activity context (i.e., compared to an unsaturated stimulus), and with calmness in an evaluation context (i.e., compared to a darker stimulus). These context-dependent associations can be predicted with dimension-specific polarity attributions on either the activity or the evaluation dimension. A limitation is that Experiment 1 was conducted in participants' homes, on participants' computer or laptop. Therefore, we could not control the presentation of the colors and environmental conditions such as ambient lighting precisely. We expected that the impact of this concern on our results may be minor as the labels of the IAT (i.e., saturated vs unsaturated) increased the salience of the activity dimension. However, it remains a question whether the saturation dimension would influence associations between colored stimuli and emotional concepts in experimental tasks where the saturation dimension is less salient.

Experiment 2

In Experiment 2, we conducted two IATs[3] to test the dimension-specificity hypothesis for another cross-modal association that has revealed contextual differences in the literature. Research has shown that brightness as compared to darkness is associated both with valence (e.g., Adams & Osgood, 1973; Lakens et al., 2013; Meier et al., 2015) and with activity (Marks, 1978; Mattes et al., 2002; Romaiguère, Hasbroucq, Possamaï, & Seal, 1993). When reviewing these studies, we noticed that whenever associations between brightness and valence were observed, brightness differences were manipulated on a screen or on a piece of paper (e.g., Meier, Robinson, & Clore, 2004), while studies that revealed an association between brightness and activity manipulated brightness using a light fixture (e.g., Romaiguère et al., 1993). In Experiment 2, we investigated whether the concept pair brightness-darkness activates different underlying dimensions, and would thus lead to distinct association patterns with valence and activity related concepts, depending on the physical presentation of the brightness stimuli.

Although both the screen and light fixture are light emitting sources, they are perceived differently. Brightness differences on a screen are perceived as black and white on a grey surface, as if ink on paper, while brightness differences in a light fixture are perceived as magnitude differences. Theoretically, a distinction is made between prothetic and metathetic dimensions (as defined by Stevens, 1957; see Smith & Sera, 1992; Spence, 2011; P. Walker & L. Walker, 2012; Walsh, 2013). Prothetic dimensions, or magnitude dimensions, are dimensions defined by quantity, or by 'how much', such as loudness, intensity or size. Metathetic dimensions can be discriminated by 'what kind' such as hue (Stevens, 1957). Light in a fixture is perceived as a prothetic dimension (i.e., illuminant brightness, see Marks, 1987; Smith & Sera, 1992; P. Walker & L. Walker, 2012), brightness differences on a screen are perceived as a methathetic dimension (i.e., surface brightness, or black vs white, see Marks, 1987; Walker, 2012). Studies have revealed distinct association patterns of bright vs dark stimuli, depending on the physical presentation. For example, bright lights are associated with loud sounds rather than quiet sounds, whereas no associations emerge between white and loudness (e.g., Marks, 1987).

The results of our pilot Study 1 (see Appendix A in the supplementary materials) show that brightness differences, when presented on a screen, are most strongly discriminated on the evaluation dimension. However, when brightness differences are presented in a light fixture, they are mostly differentiated in terms of activity and potency. Based on our pilot work, we predicted that whether the evaluation or activity dimension becomes salient in a task depend on how brightness stimuli are presented (i.e., as a metathetic dimension in the form of black and white on a screen, or as a prothetic dimension in the form of a light fixture). As a consequence, we expected that cross-modal associations between brightness-darkness, and aggression-calmness would be influenced by the way the brightness stimuli are presented.

Experiment 2A

In Experiment 2A, we tested the associations between brightness presented on a screen (i.e., black vs white) and aggression and calmness related concepts. Based on our pilot study and previous experiments (e.g., Marks, 1978; P. Walker & L. Walker, 2012), we expected that screen based brightness differences (i.e., black and white stimuli) would have the highest conceptual distance on the evaluation dimension. The target labels bright-dark are expected to have the highest conceptual distance on the evaluation dimension as well (Adams & Osgood, 1973; Osgood et al., 1957). Because aggression-calmness (as presented in word stimuli and attribute labels) would have equal distances on the evaluation and the activity dimension, we expected that in the IAT, the evaluation dimension would receive the most weight, and thus would become most salient. Brightness and calmness were expected to form the plus pole on the evaluation dimension, whereas darkness and aggression were expected to form the minus pole on the evaluation dimension. Based on these polarity attributions, brightness and calmness, and darkness and aggression, were expected to be associated in Experiment 2A.

Method

Participants

Forty-three students at Eindhoven University of Technology completed the screen brightness IAT voluntarily for a monetary compensation of 10 euro.

Materials

Participants were asked to categorize calm and aggressive words, and black and white figures into the categories aggressive, calm, brighter ('helderder' in Dutch), darker ('donkerder' in Dutch). The aggressive and calm words were identical to Experiment 1A. The light stimuli consisted of white (111.8 cd/m²) and black (0.28 cd/m²) shapes, which captured almost the whole screen (i.e., 100% in width, 75% in height). The background was grey (32.8 cd/m²).

Procedure and design

Participants completed the test in isolation in individual cubicles in front of computers. In other aspects, the design and procedure of the IAT was similar to the procedure of Experiment 1A, except for the software with which the presentation of the stimuli and registration of the responses were controlled by (i.e., E-prime), and the number of trials (i.e., 48 trials in each critical block, and 24 trials in the practice blocks). In addition, the intertrial interval was 500 milliseconds.

Results

Erroneous responses (7%) and extremely fast and slow responses (5%) were excluded from the analysis. We calculated the mean response times in milliseconds for each participant for the two critical blocks. Response latencies were shorter when the categories aggressive and darker (and calm and brighter) shared the same response key (M = 548 ms, SD = 62 ms) compared to when the categories aggressive and brighter (and calm and darker) shared the same response key (M = 730 ms, SD = 172 ms), 95% CI [138.1, 226.21], JZS BF_{10} = 56248620.08, $t(42) = 8.34$, $p < .001$, Hedges' g = 1.39, 95% CI [0.96, 1.85]. These results support the idea that a cross-modal association emerged between brightness and calmness, and darkness and aggression, when brightness stimuli are presented on the screen (i.e., black and white figure stimuli).

Experiment 2B

In Experiment 2B, we tested the associations between brightness differences presented in a light fixture and aggression and calmness related concepts. Aggression as opposed to calmness (presented in stimulus words and attribute labels) was expected to activate the evaluation and activity dimension, as aggression-calmness is conceptually distant on the activity as well as the evaluation dimension (Russell & Mehrabian, 1977; pilot Study 2, see Appendix B in the supplementary materials for the results). Based on pilot Study 1 (see Appendix A in the supplementary materials for the results), and previous experiments (Marks, 1978; Romaiguère et al., 1993), we expected that the bright-dark stimuli as presented in a light fixture, would have the highest conceptual distance on the activity dimension. In contrast, the target labels bright-dark are expected to have the highest conceptual distance on the evaluation dimension (Adams & Osgood, 1973; Osgood et al., 1957). However, at the outset of the experiment, we were unsure about the *relative* contribution of the stimuli and the labels to the overall weight of the salient dimension. If the conceptual distance between brightness-darkness presented in a light fixture would be higher on the activity dimension compared to the conceptual distance between the labels bright-dark on the evaluation dimension, the activity dimension would become salient, and therefore brightness and aggression, and darkness and calmness, would become associated. However, if the conceptual distance between brightness-darkness presented in a light fixture on the activity dimension would be smaller than the conceptual distance on the evaluation dimension between the labels bright-dark, the evaluation dimension would become salient, and therefore an association between brightness and calmness, and darkness and aggression would emerge.

Method

Participants

Forty participants who did not participate in other experiments reported here, all students at Eindhoven University of Technology, volunteered to participate in the light fixture IAT for partial course credits.

Materials

Participants were asked to categorize calm and aggressive words, and a light fixture that was either on or off into the categories aggressive, calm, brighter, darker. The aggressive and calm words were identical to Experiment 1A. The stimuli consisted of a bright Philips Hue LED (835 cd/m²) and a dark Philips Hue LED (off). The light was placed on the table, in front of the screen (see **Figure 4** for a photograph of the setup). The Philips Hue was controlled via a system that relied on Wi-Fi, which caused a delay between sending and receiving data to the lights and program. This delay was about 400 milliseconds. Therefore, we included a similar delay in the word trials. The stimulus presentations in the light fixture task thus differed from the screen brightness version, but not in any way that it would confound our hypothesis, based on relative differences within both tasks. The design and procedure were identical to Experiment 2A.

Results
Erroneous responses (6%) and extremely fast and slow responses (5%) were excluded from analysis. We calculated the mean response times in milliseconds for each participant for the two critical blocks. The response latencies were shorter when the categories aggressive and darker (and calm and brighter) shared the same keys (M = 806 ms, SD = 204 ms) compared to when the categories aggressive and brighter and calm and darker shared the same keys, (M = 898 ms, SD = 265 ms), 95% CI [26.87, 158.05], JZS BF_{10} = 5.59, $t(39)$ = 2.85, p = .007, Hedges' g = .38, 95% CI [0.11, 0.67]. These results show that a cross-modal association emerged between brightness and calmness, and darkness and aggression when brightness was presented in a light fixture. To investigate whether this observed IAT effect is significantly smaller than the effect observed in the screen brightness IAT (i.e., Experiment 2A), we conducted a repeated measures ANOVA with presentation of brightness stimuli (i.e., screen brightness vs brightness in a light fixture) included as confounding variable. The results showed a significant interaction between presentation of brightness stimuli and congruency, $F(1, 81)$ = 5.4, p = .023, η_p^2 = .06. These results suggest that the observed IAT effect in Experiment 2B is significantly smaller than the observed IAT effect in Experiment 2A.

Figure 4: Photograph of the setup of the bright-dark, aggressive-calm IAT with brightness and darkness presented in a light fixture (Experiment 2B).

Discussion
The results of Experiment 2 indicate that in this specific task, regardless of whether the stimuli were presented on the screen or in a light fixture, brightness was associated with calmness, and darkness with aggression. The significant reduction in the effect size between Experiments 2A and 2B suggests that there is indeed a difference in strength of cross-modal association as a function of the way brightness differences are presented. However, the relative weights of the opposition on the activity dimension of the stimuli presented as light fixture seems to not have been strong enough to determine the final cross-modal association that emerged. These results suggest that the labels bright-dark formed an opposition on the evaluation dimension that was stronger, instead of weaker, than the opposition of the brightness-darkness light fixture stimuli on the activity dimension. To empirically examine this post-hoc explanation, we performed Experiment 3. We set out to test the idea that the use of labels more strongly related to the activity dimension would lead to an association between brightness and aggression in the IAT when the stimuli are presented in a light fixture.

Experiment 3
In Experiment 3, we aimed to manipulate the task context such that the bipolar oppositions in the experimental task would activate the activity dimension to a greater extent than in Experiment 2. We conducted two IATs, which were identical to the IATs in Experiment 2 except for the labels. Instead of brighter-darker, we used 'more intense' ('feller' in Dutch) – dimmer (also 'dimmer' in Dutch). Our pilot Study 2[4] revealed that these labels are strongly associated with the activity dimension, while the labels brighter-darker are more strongly associated with the evaluation dimension. Using these labels should therefore increase the salience of the activity dimension to a greater extent than the brighter-darker labels used in Experiment 2.

Experiment 3A
In Experiment 3A, we tested the associations between brightness presented on a screen (i.e., black-white figures) and aggression and calmness related concepts in an activity context. Based pilot Study 1 (see Appendix A in the supplementary materials for the results) and previous studies (e.g., Marks, 1978; P. Walker & L. Walker, 2012), we expected that screen based brightness differences (i.e., black and white stimuli) would have the highest conceptual

distance on the evaluation dimension. Based on pilot Study 2, we expected that the target labels intense-dim would have the highest conceptual distance on the activity dimension. Aggression-calmness (as presented in stimulus words and attribute labels) would have equal dimension distances on the activity and evaluation dimension (Russell & Mehrabian, 1977). Hence, in this IAT, the received weight for the activity and evaluation dimension would be approximately equal. However, the results of pilot Study 1 (see Appendix A in the supplementary materials) and Experiment 2 suggest that for black and white figures, the distance on the evaluation dimension is high, whereas black and white figures do not differ in terms of activity. Therefore, we expected that the evaluation dimension would receive slightly more weight than the activity dimension, and would become most salient. Brightness and calmness should consequently form the plus pole on the evaluation dimension, whereas darkness and aggression should form the minus pole. This should lead brightness and calmness, and darkness and aggression, to become associated. This association could be less pronounced (i.e., a smaller effect size) compared to Experiment 2A.

Method

Participants

Forty-one participants, all students of Eindhoven University of Technology, voluntarily participated to the IAT for partial course credits or a monetary compensation of 3 euro. We collected the data in two periods. In the first period 22 participants completed the IAT for partial course credits.

Design and Procedure

During the first data collection, the labels of the test were Intense, Dim, Aggressive, and Calm. During the second data collection, the labels of the test were 'more intense' ('feller' in Dutch) and dimmer ('dimmer' in Dutch). In all other aspects, the design and procedure were identical to Experiment 2A.

Results

Erroneous responses (7%) and extremely fast and slow responses (6%) were excluded from analysis. We calculated the mean response times in milliseconds for each participant for the two critical blocks. As in Experiment 2A, participants responded faster when the categories aggressive and dimmer, and calm and intense shared the same response keys (M = 651 ms, SD = 183 ms), compared to when aggressive and intense and dimmer and calm shared the same keys (M = 734 ms, SD = 141 ms), 95% CI [21.6, 145.41], JZS BF_{10} = 4.24, $t(40) = 2.73$, $p = .009$, Hedges' g = 0.5, 95% CI [0.12, 0.89]. These results support the idea that a cross-modal association emerged between brightness and calmness, and darkness and aggression when brightness was presented on the screen (i.e., black and white figures). To investigate whether this observed IAT effect is significantly smaller than the effect observed in the screen brightness IAT in an evaluation context (i.e., Experiment 2A), we conducted a repeated measures ANOVA with IAT context (i.e., evaluation vs activity related labels) as confounding variable. The results showed a significant interaction between presentation of brightness stimuli and congruency, $F(1, 82) = 6.98$, $p = .01$, $\eta_p^2 = .08$. As predicted, these results suggest that the observed IAT effect in Experiment 3A is significantly smaller than the observed IAT effect in Experiment 2A.

Experiment 3B

In Experiment 3B, we tested the associations between brightness presented in a light fixture (i.e., bright vs dark) and aggression and calmness related concepts in an activity context. Based on our pilot Study 1 (see Appendix A in the supplementary materials for the results) and previous experiments (e.g., Marks, 1978; P. Walker & L. Walker, 2012), we predicted that when brightness is presented in a light fixture, the conceptual distance between bright-dark (as presented in as a light fixture that is either on or off) would be higher on the activity dimension as compared to the evaluation dimension. The target labels intense-dim would have the highest distance on the activity dimension (based on pilot Study 2). Because the concept-pair aggression-calmness (as presented in word stimuli and attribute labels) would have equal conceptual distances on the evaluation as well as the activity dimension (Russell & Mehrabian, 1977), we expected that in the task, the activity dimension will receive the most weight, and thus would become most salient. Brightness and aggression were expected to form the plus pole on the activity dimension whereas darkness and calmness were expected to form the minus pole. Based on these polarity attributions, brightness and aggression, and darkness and calmness were expected to become associated.

Method

Participants

Forty-three (new) participants, all students of Eindhoven University of Technology, voluntarily participated to the light fixture IAT for partial course credits or a monetary compensation of 3 euro. We collected the data in two times. The first time, 20 participants conducted the IAT for partial course credits.

Design and Procedure

The labels of the test were 'more intense', dimmer, aggressive, and calm. In all other respects, the design and procedure were identical to Experiment 2B.

Results

Erroneous responses (6%) and extremely fast and slow responses (3%) were excluded from analysis. We calculated the mean response times in milliseconds for each participant for the two critical blocks. As expected, participants responded faster when the categories aggressive and 'feller' and calm and dimmer shared the same response keys (M = 923 ms, SD = 164 ms) compared to when aggressive and dimmer and calm and intense shared the same response keys (M = 1033 ms, SD = 213 ms), 95% CI [61.38, 159.26], JZS BF_{10} = 492.38, $t(42) = 4.55$, $p <$

.001, Hedges' g = .57, 95% CI [0.3, 0.86]. There is a clear main effect for response times between the light fixture and the screen brightness IAT, which can be explained by the WiFi delay of the LED. Compared to Experiment 2B, these data suggest that using labels strongly associated with the activity dimension were sufficient to reverse the cross-modal mapping in the IAT with a light fixture.[5] See **Figure 5** for a graph with the mean response times on the two critical blocks for Experiments 2 and 3.

Discussion

Whereas in Experiment 2B brightness presented in a light fixture was associated with calmness, in Experiment 3B, the same stimulus was associated with aggression. These results suggest that while in Experiment 2B the evaluation dimension was salient, in Experiment 3B the *activity* dimension was salient when light was presented in a fixture. The associations between brightness-darkness and aggression-calmness when brightness differences were presented on a screen were similar across Experiments 2A and 3A. Brightness was associated with calmness, and darkness was associated with aggression, although as predicted, the strength of this association in Experiment 3A was smaller than the strength of the association found in Experiment 2A. Together with Experiment 2, the results of Experiment 3 provide further support for the dimension-specificity hypothesis. The results suggest that category labels shape the task-specific context in such a way that they determine which underlying dimension of meaning becomes salient, and which cross-modal association emerges. See **Table 1** for a visual summary of the design and results of Experiments 1 to 3.

General Discussion

Context plays a crucial role when constructing the meaning of concepts (e.g., Elliot & Maier, 2012; Gawronski et al., 2014; Mesquita et al., 2010; Schwarz, 2007). Researchers have emphasized the importance of developing mid-

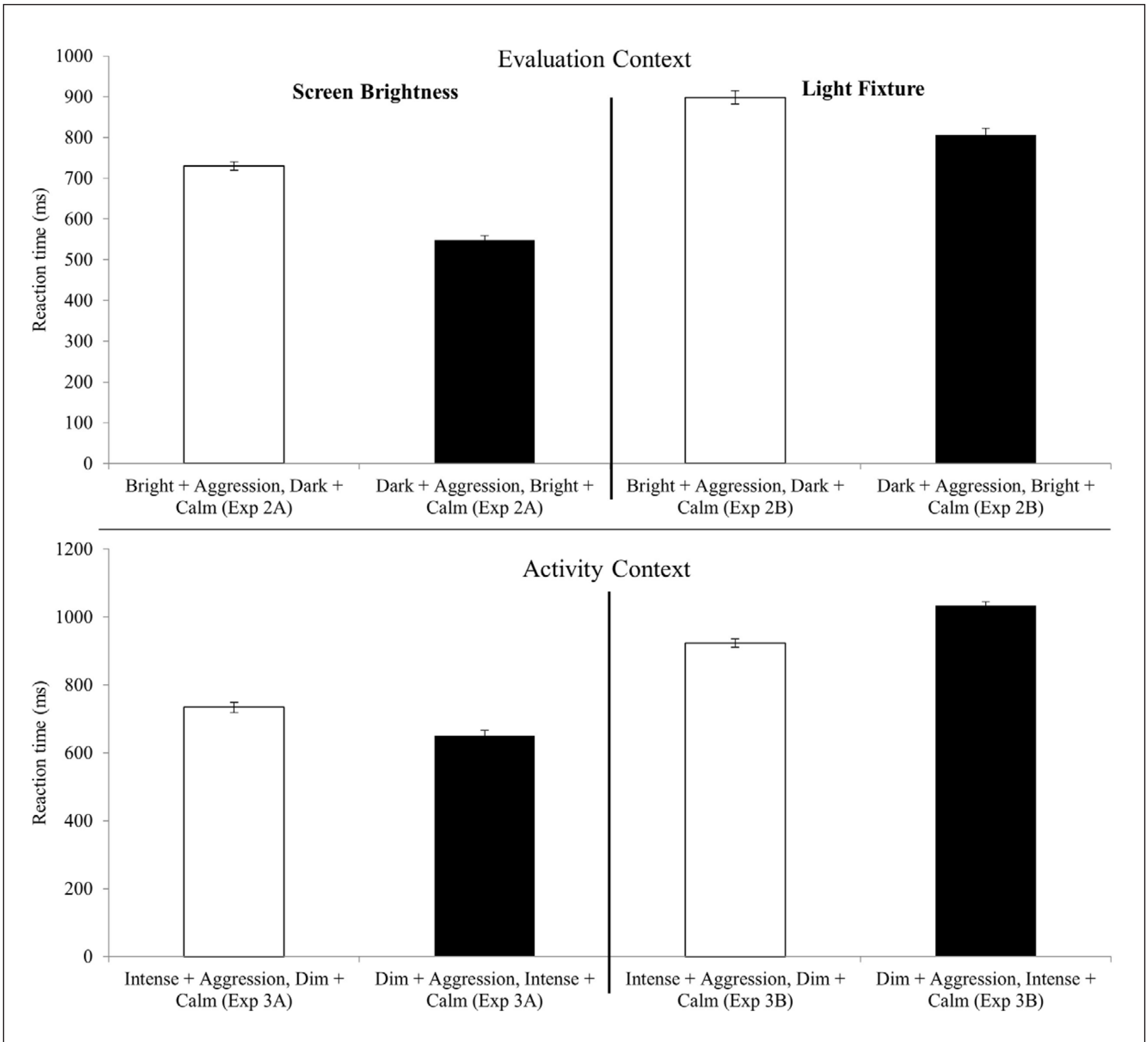

Figure 5: Mean reaction times in milliseconds of Experiments 2 and 3 for the critical blocks of the screen brightness IATs (left) and the light fixture IATs (right) in an evaluation (above) and activity context (below). Error bars represent standard errors of the mean.

Table 1: A visual summary of the design and results of Experiment 1, Experiment 2, and Experiment 3.

Exp.	Labels	Concrete concepts	Affective abstract concepts	Context manipulation	Predicted dimension	Prediction of associations	Results
1A	bright vs dark/ aggressive vs calm	brightness (computer): bright purple vs dark purple	aggressive (furious, murder, enraged, destroy) vs calm (zen, calm, relaxed, peaceful)	opposing stimulus (compared to 1B)	evaluation	bright + calm, dark + aggressive	confirmed
1B	saturated vs unsaturated/ aggressive vs calm	saturation (computer): saturated purple vs unsaturated purple	aggressive vs calm – same as 1A	opposing stimulus (compared to 1A)	activity	saturated + aggressive, unsaturated + calm	confirmed
2A	brighter vs darker/ aggressive vs calm	brightness (computer): bright vs dark	aggressive vs calm – same as 1A	presentation of brightness stimuli (compared to 2B)	evaluation	bright + calm, dark + aggressive	confirmed
2B	brighter vs darker/ aggressive vs calm	brightness (light fixture): bright vs dark	aggressive vs calm – same as 1A	presentation of brightness stimuli (compared to 2A)	activity/evaluation	bright + aggressive, dark + calm or bright + calm/dark + aggressive	bright + calm, dark + aggressive (weaker association than 2A)
3A	intense vs dim (1) intenser vs dimmer (2)/aggressive vs calm	brightness (computer): bright vs dark	aggressive vs calm – same as 1A	IAT labels (compared to 3B)	evaluation	bright + calm, dark + aggressive	confirmed (weaker association than 2A)
3B	intenser vs dimmer/ aggressive vs calm	brightness (light fixture): bright vs dark	aggressive vs calm – same as 1A	IAT labels (compared to 3A)	activity	bright + aggressive, dark + calm	confirmed

level theories that incorporate context-effects in models of human cognition (e.g., Elliot, 2015). So far, the development of theories to explain and predict context effects has proven to be one of the great challenges in psychology.

To understand when and how the affective meaning of a concept is activated in specific contexts, we proposed the dimension-specificity hypothesis, based on the affective theory of meaning (Osgood et al., 1957) and the polarity correspondence principle (Proctor & Cho, 2006). The dimension-specificity hypothesis postulates that associations between concrete and affective abstract concepts might emerge based on the conceptual distances between opposing concepts on the dimensions of meaning (i.e., evaluation, activity, & potency dimension), leading to one salient dimension, on which concepts in turn are structured according to the attribution of plus and minus poles. Based on the idea of polarity correspondence, we expected that the concepts that both form the plus pole on the salient dimension would become related, just as the concepts that both form the minus poles.

In three series of experiments, we tested the dimension-specificity hypothesis by predicting the associations between aggression-related concepts and colors, saturation, and brightness. We manipulated the context by adjusting the opposition in the stimulus set (Experiments 1), the presentation of the stimuli (i.e., screen brightness or brightness presented with a light fixture, Experiment 2), and the labels in the task (Experiment 3). Providing further support for the influence of the opposing stimuli on the emergence of cross-modal associations, Experiment 1 revealed that associations between brightness, saturation, and aggression could be predicted using dimension-specific polarity attributions. Experiments 2 and 3 revealed that the presentation of the stimulus in combination with the category labels shaped the task-specific context in such a way that different dimensions became salient, which moderated the association between brightness and aggression. Together, these results support the dimension-specificity hypothesis.

Predicting context-dependent associations

Our results suggest that bipolar opposition as determined in a task (e.g., an IAT) is of crucial importance to predict associations between concrete and affective abstract concepts. In addition, our results are conceptually in line with theoretical frameworks that stress the importance of opposition and alignment along dimensions (Becker, 1980; Lakens, 2012; Lakens et al., 2012; Paradis & Willners, 2011; Scherer & Lambert, 2009; P. Walker, 2016; L. Walker & P. Walker, 2016; Willners & Paradis, 2010). Which dimension of meaning became salient in a task, depended largely on the opposition in the concept pairs of the stimuli presented during the task. For example, brighter as compared to darker colors activated the evaluation dimension, whereas saturated as compared to unsaturated colors activated the activity dimension (Experiment 1). Our results suggest that when the distance between two concepts of a pair on a dimension was high (i.e., the concept pair forms a strong opposite), the weight given to that dimension was high, which in turn increased the likelihood that the dimension would become salient in the task. Although it has proven difficult to predict the values of the distances between the concepts brightness-darkness (see for example Experiment 2), these assumptions can be empirically examined, and corrected (Experiment 3).

An important question for future research is how the distances between concept pairs can be accurately determined a priori, especially when there is no relevant literature to build on. This question has parallels with the (cognitive linguistic) question of when people perceive concepts to be antonyms, and why some word pairings are better than others (e.g., Herrmann, Chaffin, Daniel, & Wool, 1986; Murphy & Andrew, 1993; Paradis & Willners, 2011; Paradis, Willners, & Jones, 2009). For example, Paradis and colleagues (2009) propose that the division between strong and weak opposites depends on the context, but that there are canonical antonyms that are more robustly rooted in memory and language, and thus are perceived as strong opposites. These canonical antonyms are the "conventionalized expressions of the opposing poles" (Paradis et al., 2009, p. 388). For example, fast versus slow form canonical antonyms on the dimension speed. Slow versus rapid are also antonyms on the activity dimension, but less strongly, and are not considered canonical antonyms.

Canonical antonyms are likely to produce opposite responses in word association tasks. For example, when indicating the first association people think of, most people mention white when they see the word black, whereas they respond to the word green without one strong opposite: People mention the word grass, or contrasting colors such as red, blue, or yellow (Jenkins, 1970). This indicates that black versus white could form a stronger opposite compared to red versus green. Free association tasks might thus be one fruitful way to determine the strength of opposition between concepts a-priori, which would allow researchers to predict which cross-modal associations will emerge.

Our results are in line with studies that show that specific cross-modal associations depend on opposing stimuli available in the task (e.g., Melara & Marks, 1990; L. Walker & P. Walker, 2016) and on the salience of dimensions (P. Walker, L. Walker, & Francis, 2015). However, importantly, we did not aim to suggest that *all* cross-modal associations can be predicted based on affective dimensions of meaning and the dimension-specificity hypothesis. For example, the evaluation, activity, and potency dimensions did not seem to underlie cross-modal associations between surface brightness and size (P. Walker & L. Walker, 2012, p. 1236). In addition, associations between two sensory modalities which emerge based on neural connections present at birth, such as brightness and loudness (i.e., structural associations, Spence, 2011) seem to be better predicted by means of similarity on a universal magnitude or intensity dimension (Marks, 1978; Walsh, 2003) than on similarity on the dimensions of affective meaning. Moreover, people seem to be able to evaluate and value some concepts based on an internal physiological or psychological scale, which does not necessarily depend on the context, such as ambient temperature (Hsee & Zhang, 2010). However, we propose that polarity correspondence on specific dimensions of meaning might be one way based on which context-dependent cross-modal associations between concrete and affective abstract concepts might emerge. Whether the dimensions of meaning also underlie (specific) associations between two sensory modalities remains a question for future research.

Contextual Associations

Our results support the contextual nature of cross-modal associations. Our data show that the many features that can be identified in a cognitive task create a specific context, such as the choice of polar opposites in the stimulus set, the way stimuli are presented (i.e., brightness presented on the screen or in a light fixture), as well as the labels used in the task. All these aspects influenced which underlying dimension of meaning became salient.

Whether associations are stable and represented in memory (e.g., Fazio, 2007), or whether they are constructed on the spot based on contextual features (e.g., Rothermund & Wentura, 2004; Schwarz, 2007; Smith, 1996) remains an open question. One can ask whether the meaning of the concept brightness is stored as active *and* positive in memory, and depending on the context one of these meanings is activated, or whether the concept brightness lacks stable associations, and its meaning is constructed on the fly, dependent on the context. Although the current studies were not designed to address such hypotheses, this line of research raises the question whether it is in principle possible to have a context-free representation of the meaning of a concept. It seems impossible to design an experiment without activating some context. If there is indeed no such thing as a context-free meaning, this further highlights the importance of creating models that predict how context-dependent meaning emerges.

Limitations and future research questions

To predict context-dependent cross-modal associations, we proposed that a (conceptual) weighting process would determine which of the activated dimensions becomes most salient in the task specific context. Although we believe that this mechanism can be quantified precisely for cross-modal associations based on future research, we refrained from such an exact quantification in the current manuscript, as we aimed for a conceptual, but not a mathematical verification of the proposed mechanism. The dimension-specificity hypothesis makes several predictions that allow it to be falsified in future studies. First, we should expect cross-modal associations to be stronger when polar opposites are present in the task, rather than absent. Furthermore, it predicts that cross-modal associations should differ across contexts where different dimensions of meaning are salient. Testing and replicating these hypothesized effects would contribute to falsifying the idea of polarity correspondence based on dimensions of meaning.

The dimensional approach to conceptual meaning we build on in the current manuscript has received some criticism. For example, Murphy (2002) has pointed out that the dimensions by Osgood and colleagues were too general to actually describe the meaning of concepts. As Murphy (2002, p. 515) said: "Better you should know that cats meow and have whiskers than you should know their potency and evaluation." Whereas Murphy (2002) focuses on a categorical approach to the process of meaning giving based on features, Osgood and colleagues stress the importance of affect. Even though we believe both approaches are necessary to fully understand how people give meaning to concepts, with the current studies we have focused on the connotative, affective meaning of concepts. The three dimensions of meaning identified by Osgood and colleagues might not be sufficient to differentiate between concepts based on features, or to describe the denotative meaning of concepts, they are extremely suitable to measure the *affective* meaning (Osgood, 1969). The affective meaning of stimuli seems to be a potential basis for cross-modal associations, and understanding the affective meaning of concepts is arguably a very important aspect of understanding human cognition.

In our studies, we could predict cross-modal associations using only the evaluation and activity dimension. Differentiating between the activity and the potency dimension was difficult, as the two dimensions seemed to collapse into a combined dimension. This would be in line with the theoretical work of Osgood and colleagues (1957), who suggested that the activity and potency dimension can merge into one unified 'dynamism factor' when evaluating certain concepts (e.g., 'sociopolitical concepts', p. 74). As Osgood and colleagues (1957) pointed out, the specific order and importance of the dimensions may change as a function of specific contexts. In addition, Osgood and colleagues mentioned that it is very likely that *additional* dimensions are important for different studies and purposes. Throughout their different semantic differential studies, the three affective dimensions of meaning (i.e., evaluation, activity, and potency) turned out to explain most of the variance, but the three dimensions did not explain *all* variance. Future studies might investigate the existence and importance of additional dimensions of meaning, and their relevance in specific settings.

In the current studies, participations were mostly students from Technical University of Eindhoven, and therefore our results might not be representative for other populations (i.e., populations other than people from Western, Educated, Industrialized, and Democratic societies, or WEIRD, see Henrich, Heine, & Norenzayan, 2010). However, although the meaning people give to stimuli and concepts might be culture dependent, based on these meanings (which can be assessed with pilots, see for example Pilot studies 1 and 2), associations between concrete and affective abstract concept-pairs can be predicted for people from other cultures, where we expect the dimension-specificity hypothesis will also play a role. Of course, whether the dimension-specificity hypothesis indeed predicts cross-modal associations between brightness, colors, and aggression across cultures remains a question for further research. In this light, internet-based methods provide the opportunity to increase ecological validity, though the presentation of stimuli cannot be controlled precisely (e.g. Woods et al., 2013).

In addition to the context manipulations used in the current set of three experiments (the pairs of stimuli in the task, the way stimuli were presented, and the labels used in the task), there are many other ways in which context can be manipulated. Many additional contextual cues have the potential to influence which dimension becomes salient within a task, such as the task instructions (e.g., Banks et al., 1975; Foroni & Mayr, 2005), attention to specific cues such as the background color used in a task or the affective dimension of a stimulus (e.g., Gawronski, Rydell, Vervliet, & de Houwer, 2010; Spruyt, De Houwer, Hermans, & Eelen, 2007), but also individual differences such as a person's emotional state can influence the way concepts become related (e.g., Gilet & Jallais, 2011; Hanze & Meyer, 1998). Future studies might explore additional ways in which the salience of the underlying dimension of meaning can be manipulated, and thus how the specific association that emerges between stimuli is context-dependent.

Conclusion

The current findings highlight that both structural similarities (i.e., polarity correspondence) as well as the content of the concepts (i.e., the specific dimension along which concepts were aligned) are of crucial importance for understanding how cross-modal associations emerge in specific contexts. The dimension-specificity hypothesis provides an important first step to predict how and when context-dependent associations will emerge. Predicting specific cross-modal associations between concrete and affective abstract concepts seems impossible without taking the context into account.

Data accessibility statement

All the stimuli, presentation materials, data, and analysis scripts are available from the Open Science Framework https://osf.io/agvz3/.

Additional Files

The additional files for this article can be found as follows:

- **Appendix A.** Pilot Study 1. DOI: https://doi.org/10.1525/collabra.110.s1
- **Appendix B.** Pilot Study 2. DOI: https://doi.org/10.1525/collabra.110.s1
- **Appendix C.** Robust Statistics. DOI: https://doi.org/10.1525/collabra.110.s1

Notes

[1] To be precise, in the current manuscript, we refer to concrete concepts as concepts which can be represented as physical entities, whereas affective abstract concepts are "entities that are neither purely physical nor spatially constrained" (Barsalou & Wiemer-Hastings, p. 129). More specifically, we define concrete concepts as features from (visual) sensory modalities (e.g., a white versus black colored patch), and abstract concepts as affective words (e.g., aggression versus calmness).

[2] Experiments 1A and 1B were conducted at participants' home, and therefore the xyY values are an approximation, based on colors presented on a standard RGB monitor.

[3] Experiment 2 additionally contained 2 IATs with dynamic brightness stimuli (i.e., an increase or decrease in screen or luminance brightness). However, the results of those two IATs are not relevant for the current manuscript, and are therefore not reported.

[4] Bright ('helder' in Dutch) was judged as more positive (M = 7.18, SD = 1.05) than dark ('donker' in Dutch, M = 3.95, SD = 1.56), $t(38) = 9.57$, $p < .001$, Hedges' g = 2.39, 95% CI [1.69, 3.17]. However, dark was judged as more aggressive (M = 5.71, SD = 1.54) than bright (M = 2.71, SD = 1.18), $t(34) = 8.69$, $p < .001$, Hedges' g = –2.14, 95% CI[–2.89, –1.46). Bright was not significantly judged as more active (M = 4.02, SD = 1.75) than dark (M = 3.97, SD = 1.94), $t(39) = –0.31$, p = .896, Hedges' g = .03, 95% CI [–.39, .44].

The concept intense ('fel' in Dutch) was judged as more active (M = 7.54, SD = 1.27) compared to dimming ('dimmen' in Dutch, M = 4.82, SD = 1.71), $t(38) = 7.44$, $p < .001$, Hedges' g = 1.8, 95% CI [1.17, 2.41]. In addition, intense was judged as more aggressive (M = 6.91, SD = 1.44) than dimming (M = 3.97, SD = 1.22), $t(34) = 9.59$, $p < .001$, Hedges' g = 2.15, 95% CI [1.5, 2.88]. Intense was not significantly judged as more negative (M = 4.3, SD = 1.82) than dimming (M = 4.95, SD = 1.43), $t(38) = –1.66$, p = .105, Hedges' g = –.38, 95% CI [–.86, .08]. See Appendix B in the supplementary materials for the full description and results of pilot Study 2.

[5] Because the simple effect of Experiment 3B is statistically significant in the opposite direction than the effects of Experiment 2B, any interaction comparing the results across experiments is also statistically significant.

Funding Informations

The current work was made possible by financial support received from the Netherlands Organization for Scientific Research, under project number 314-99-112.

Competing Interests

The authors have no competing interests to declare.

References

Adams, F. M., & **Osgood, C. E.** (1973). A cross-cultural study of the affective meanings of color. *Journal of Cross-Cultural Psychology*, *4*(2), 135–156. DOI: https://doi.org/10.1177/002202217300400201

Banks, W. P., Clark, H. H., & **Lucy, P.** (1975). The locus of the semantic congruity effect in comparative judgments. *Journal of Experimental Psychology: Human Perception and Performance*, *1*(1), 35–47. DOI: https://doi.org/10.3758/BF03195260

Barrett, L. F., Wilson-Mendenhall, C. D., & **Barsalou, L. W.** (2014). A psychological construction account of emotion regulation and dysregulation: The role of situated conceptualizations. In: Gross, J. J. (Ed.), *Handbook of emotion regulation*, 447–465. New York: Guilford.

Barsalou, L. W., & **Wiemer-Hastings, K.** (2005). Situating abstract concepts. In: Pecher, D., & Zwaan, R. (Eds.), *Grounding Cognition: The role of perception and action in memory, language, and thought*, 129–163. New York: Cambridge University Press. DOI: https://doi.org/10.1017/CBO9780511499968.007

Becker, C. A. (1980). Semantic context effects in visual word recognition: An analysis of semantic strategies. *Memory & Cognition*, *8*(6), 493–512. DOI: https://doi.org/10.3758/BF03213769

Blair, I. V. (2002). The malleability of automatic stereotypes and prejudice. *Personality and Social Psychology Review*, *6*(3), 242–261. DOI: https://doi.org/10.1207/S15327957PSPR0603_8

Crisinel, A.-S., & **Spence, C.** (2009). Implicit association between basic tastes and pitch. *Neuroscience Letters*, *464*(1), 39–42. DOI: https://doi.org/10.1016/j.neulet.2009.08.016

Dael, N., Perseguers, M. N., Marchand, C., Antonietti, J. P., & **Mohr, C.** (2016). Put on that colour, it fits your emotion: Colour appropriateness as a function of expressed emotion. *The Quarterly Journal of Experimental Psychology, 69*(8), 1619–1630. DOI: https://doi.org/10.1080/17470218.2015.1090462

De Houwer, J., Teige-Mocigemba, S., Spruyt, A., & **Moors, A.** (2009). Implicit measures: A normative analysis and review. *Psychological Bulletin*, *135*(3), 347–368. DOI: https://doi.org/10.1037/a0014211

Demattè, M. L., Sanabria, D., & **Spence, C.** (2007). Olfactory–tactile compatibility effects demonstrated using a variation of the implicit association test. *Acta Psychologica, 124*(3), 332–343. DOI: https://doi.org/10.1016/j.actpsy.2006.04.001

Elliot, A. J. (2015). Color and psychological functioning: A review of theoretical and empirical work. *Frontiers in Psychology*, *6*(368), 1–8. DOI: https://doi.org/10.3389/fpsyg.2015.00368

Elliot, A. J., & **Maier, M. A.** (2012). Color-in-context theory. *Advances in Experimental Social Psychology*, *45*, 61–125. DOI: https://doi.org/10.1016/B978-0-12-394286-9.00002-0

Elliot, A. J., & **Maier, M. A.** (2014). Color psychology: Effects of perceiving color on psychological functioning in humans. *Annual Review of Psychology, 65*, 95–120. DOI: https://doi.org/10.1146/annurev-psych-010213-115035

Elliot, A. J., & **Pazda, A. D.** (2012). Dressed for sex: Red as a female sexual signal in humans. *PLoS One, 7*(4), e34607. DOI: https://doi.org/10.1371/journal.pone.0034607

Elliott, E. M., Cowan, N., & **Valle-Inclan, F.** (1998). The nature of cross-modal color-word interference effects. *Attention, Perception, & Psychophysics, 60*(5), 761–767. DOI: https://doi.org/10.3758/BF03206061

Faul, F., Erdfelder, E., Lang, A.-G., & **Buchner, A.** (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*, 175–191. DOI: https://doi.org/10.3758/BF03193146

Fazio, R. H. (2007). Attitudes as object-evaluation associations of varying strength. *Social Cognition*, *25*(5), 603–637. DOI: https://doi.org/10.1521/soco.2007.25.5.603

Foroni, F., & **Mayr, U.** (2005). The power of a story: New, automatic associations from a single reading of a short scenario. *Psychonomic Bulletin & Review*, *12*(1), 139–144. DOI: https://doi.org/10.3758/BF03196359

Frühholz, S., Trautmann-Lengsfeld, S. A., & **Herrmann, M.** (2011). Contextual interference processing during fast categorizations of facial expressions. *Cognition & Emotion, 25*(6), 1045–1073. DOI: https://doi.org/10.1080/02699931.2010.516905

Gardner, H. (1974). Metaphors and modalities: How children project polar adjectives onto diverse domains. *Child Development*, 84–91. DOI: https://doi.org/10.2307/1127753

Gawronski, B., Rydell, R. J., Vervliet, B., & **De Houwer, J.** (2010). Generalization versus contextualization in automatic evaluation. *Journal of Experimental Psychology: General*, *139*(4), 683–701. DOI: https://doi.org/10.1037/a0020315

Gawronski, B., Ye, Y., Rydell, R. J., & **De Houwer, J.** (2014). Formation, representation, and activation of contextualized attitudes. *Journal of Experimental Social Psychology*, *54*, 188–203. DOI: https://doi.org/10.1016/j.jesp.2014.05.010

Gilet, A. L., & **Jallais, C.** (2011). Valence, arousal and word associations. *Cognition & Emotion*, *25*(4), 740–746. DOI: https://doi.org/10.1080/02699931.2010.500480

Greenwald, A. G., Banaji, M. R., Rudman, L. A., Farnham, S. D., Nosek, B. A., & **Mellott, D. S.** (2002). A unified theory of implicit attitudes, stereotypes, self-esteem, and self-concept. *Psychological Review*, *109*(1), 3–25. DOI: https://doi.org/10.1037/0033-295X.109.1.3

Greenwald, A. G., McGhee, D. E., & **Schwartz, J. L.** (1998). Measuring individual differences in implicit cognition: the implicit association test. *Journal of Personality and Social Psychology*, *74*(6), 1464–1480. DOI: https://doi.org/10.1037/0022-3514.74.6.1464

Greenwald, A. G., Nosek, B. A., Banaji, M. R., & **Klauer, K. C.** (2005). Validity of the salience asymmetry interpretation of the implicit association test: comment on Rothermund and Wentura (2004). *Journal of Experimental Psychology: General, 134*(4), 420–425. DOI: https://doi.org/10.1037/0096-3445.134.3.420

Hanauer, J. B., & **Brooks, P. J.** (2003). Developmental change in the cross-modal Stroop effect. *Perception & Psychophysics, 65*(3), 359–366. DOI: https://doi.org/10.3758/BF03194567

Hanze, M., & **Meyer, H. A.** (1998). Mood influences on automatic and controlled semantic priming. *The American Journal of Psychology*, *111*(2), 265–278. DOI: https://doi.org/10.2307/1423489

Henrich, J., Heine, S. J., & **Norenzayan, A.** (2010). The weirdest people in the world? *Behavioral and Brain*

Sciences, *33*, 61–135. DOI: https://doi.org/10.1017/S0140525X0999152X

Herrmann, D. J., Chaffin, R., Daniel, M. P., & **Wool, R. S.** (1986). The role of elements of relation definition in antonym and synonym comprehension. *Zeitschrift für Psychologie mit Zeitschrift für angewandte Psychologie, 194*(2), 133–153.

Holmes, K. J., & **Lourenco, S. F.** (2011). Common spatial organization of number and emotional expression: A mental magnitude line. *Brain and Cognition*, *77*(2), 315–323. DOI: https://doi.org/10.1016/j.bandc.2011.07.002

Hsee, C. K., & **Zhang, J.** (2010). General evaluability theory. *Perspectives on Psychological Science*, *5*(4), 343–355. DOI: https://doi.org/10.1177/1745691610374586

Hupka, R. B., Zaleski, Z., Otto, J., Reidl, L., & **Tarabrina, N. V.** (1997). The colors of anger, envy, fear, and jealousy: A cross-cultural study. *Journal of Cross-Cultural Psychology, 28*(2), 156–171. DOI: https://doi.org/10.1177/0022022197282002

Jenkins, J. J. (1970). The 1952 Minnesota word association norms. In: Postman, L., & Keppel, G. (Eds.), *Norms of word association*, 1–38. New York: Academic Press. DOI: https://doi.org/10.1016/B978-0-12-563050-4.50004-2

Kornblum, S., & **Lee, J. W.** (1995). Stimulus-response compatibility with relevant and irrelevant stimulus dimensions that do and do not overlap with the response. *Journal of Experimental Psychology: Human Perception and Performance*, *21*(4), 855–875. DOI: https://doi.org/10.1037/0096-1523.21.4.855

Kruschke, J. K. (1992). ALCOVE: an exemplar-based connectionist model of category learning. *Psychological Review*, *99*(1), 22–44. DOI: https://doi.org/10.1037/0033-295X.99.1.22

Lakens, D. (2012). Polarity correspondence in metaphor congruency effects: structural overlap predicts categorization times for bi-polar concepts presented in vertical space. *Journal of Experimental Psychology: Learning, Memory and Cognition, 38*(3), 726–736. DOI: https://doi.org/10.1037/a0024955

Lakens, D., Fockenberg, D. A., Lemmens, K. P., Ham, J., & **Midden, C. J.** (2013). Brightness differences influence the evaluation of affective pictures. *Cognition & Emotion*, *27*(7), 1225–1246. DOI: https://doi.org/10.1080/02699931.2013.781501

Lakens, D., Semin, G. R., & **Foroni, F.** (2012). But for the bad, there would not be good: Grounding valence in brightness through shared relational structures. *Journal of Experimental Psychology: General*, *141*(3), 584–594. DOI: https://doi.org/10.1037/a0026468

Lakens, D., Semin, G. R., & **Garrido, M. V.** (2011). The sound of time: Cross-modal convergence in the spatial structuring of time. *Consciousness and Cognition, 20*(2), 437–443. DOI: https://doi.org/10.1016/j.concog.2010.09.020

Marks, L. E. (1978). *The unity of the senses: Interrelations among the modalities*. New York: Academic Press. DOI: https://doi.org/10.1016/B978-0-12-472960-5.50011-1

Marks, L. E. (1987). On cross-modal similarity: Auditory–visual interactions in speeded discrimination. *Journal of Experimental Psychology: Human Perception and Performance*, *13*(3), 384–394. DOI: https://doi.org/10.1037/0096-1523.13.3.384

Mattes, S., Leuthold, H., & **Ulrich, R.** (2002). Stimulus-response compatibility in intensity-force relations. *The Quarterly Journal of Experimental Psychology: Section A*, *55*(4), 1175–1191. DOI: https://doi.org/10.1080/02724980244000152

Medin, D. L., & **Schaffer, M. M.** (1978). Context theory of classification learning. *Psychological Review*, *85*(3), 207–238. DOI: https://doi.org/10.1037/0033-295X.85.3.207

Meier, B. P., Fetterman, A. K., & **Robinson, M. D.** (2015). Black and white as valence cues. *Social Psychology*, *46*, 174–178. DOI: https://doi.org/10.1027/1864-9335/a000236

Meier, B. P., Robinson, M. D., & **Clore, G. L.** (2004). Why good guys wear white: Automatic inferences about stimulus valence based on brightness. *Psychological Science*, *15*(2), 82–87. DOI: https://doi.org/10.1111/j.0963-7214.2004.01502002.x

Melara, R. D., & **Marks, L. E.** (1990). Processes underlying dimensional interactions: Correspondences between linguistic and nonlinguistic dimensions. *Memory & Cognition, 18*(5), 477–495. DOI: https://doi.org/10.3758/BF03198481

Mesquita, B., Feldman Barrett, L. F., & **Smith, E. R.** (Eds.) (2010). *The mind in context*. New York: Guilford.

Mitchell, J. P., Nosek, B. A., & **Banaji, M. R.** (2003). Contextual variations in implicit evaluation. *Journal of Experimental Psychology: General, 132*(3), 455–469. DOI: https://doi.org/10.1037/0096-3445.132.3.455

Moller, A. C., Elliot, A. J., & **Maier, M. A.** (2009). Basic hue-meaning associations. *Emotion*, *9*(6), 898–902. DOI: https://doi.org/10.1037/a0017811

Moors, A., Spruyt, A., & **De Houwer, J.** (2010). In search of a measure that qualifies as implicit: Recommendations based on a decompositional view of automaticity. In: Gawronski, B., & Payne, K. B. (Eds.), *Handbook of implicit social cognition: Measurement, theory, and applications*, 19–37. New York: Guilford Press.

Murphy, G. L. (1996). On metaphoric representation. *Cognition*, *60*(2), 173–204. DOI: https://doi.org/10.1016/0010-0277(96)00711-1

Murphy, G. L. (2002). *The big book of concepts*. Cambridge: MIT Press.

Murphy, G. L., & **Andrew, J. M.** (1993). The conceptual basis of antonymy and synonymy in adjectives. *Journal of Memory and Language*, *32*(3), 301–319. DOI: https://doi.org/10.1006/jmla.1993.1016

Murphy, M. L. (2003). *Semantic relations and the lexicon: antonymy, synonymy and other paradigms.* New York: Cambridge University Press. DOI: https://doi.org/10.1017/CBO9780511486494

Nosofsky, R. M. (1986). Attention, similarity, and the identification–categorization relationship. *Journal of Experimental Psychology: General*, *115*(1), 39–57. DOI: https://doi.org/10.1037/0096-3445.115.1.39

Osgood, C. E., & **Richards, M. M.** (1973). From yang and yin to and or but. *Language*, *49*(2), 380–412. DOI: https://doi.org/10.2307/412460

Osgood, C. E., Suci, G. J., & **Tannenbaum, P. H.** (1957). *The measurement of meaning*. Urbana, IL: University of Illinois Press.

Paradis, C., van de Weijer, J., Willners, C., & **Lindgren, M.** (2012). Evaluative polarity of antonyms. *Lingue e Linguaggio, 11*(2), 199–214. DOI: https://doi.org/10.1007/s00221-012-3140-6

Paradis, C., & **Willners, C.** (2011). Antonymy: From convention to meaning-making. *Review of Cognitive Linguistics*, *9*(2), 367–391. DOI: https://doi.org/10.1075/rcl.9.2.02par

Paradis, C., Willners, C., & **Jones, S.** (2009). Good and bad opposites using textual and experimental techniques to measure antonym canonicity. *The Mental Lexicon*, *4*(3), 380–429.

Parise, C. V., & **Spence, C.** (2012). Audiovisual crossmodal correspondences and sound symbolism: a study using the implicit association test. *Experimental Brain Research, 220*(3–4), 319–333. DOI: https://doi.org/10.1075/ml.4.3.04par

Proctor, R. W., & **Cho, Y. S.** (2006). Polarity correspondence: A general principle for performance of speeded binary classification tasks. *Psychological Bulletin*, *132*(3), 416–442. DOI: https://doi.org/10.1037/0033-2909.132.3.416

Proctor, R. W., & **Xiong, A.** (2015). Polarity correspondence as a general compatibility principle. *Current Directions in Psychological Science*, *24*(6), 446–451. DOI: https://doi.org/10.1177/0963721415607305

Romaiguère, P., Hasbroucq, T., Possamaï, C., & **Seal, J.** (1993). Intensity to force translation: A new effect of stimulus-response compatibility revealed by analysis of response time and electromyography activity of a prime mover. *Cognitive Brain Research*, *1*(3), 197–201. DOI: https://doi.org/10.1016/0926-6410(93)90028-4

Rothermund, K., & **Wentura, D.** (2001). Figure-ground asymmetries in the implicit association test (IAT). *Zeitschrift für Experimentelle Psychologie*, *48*(2), 94–106. DOI: https://doi.org/10.1026//0949-3946.48.2.94

Rothermund, K., & **Wentura, D.** (2004). Underlying processes in the implicit association test: dissociating salience from associations. *Journal of Experimental Psychology: General*, *133*(2), 139–165. DOI: https://doi.org/10.1037/0096-3445.133.2.139

Rothermund, K., Wentura, D., & **De Houwer, J.** (2005). Validity of the salience asymmetry account of the implicit association test: Reply to Greenwald, Nosek, Banaji, and Klauer. *Journal of Experimental Psychology: General, 134*(3), 426–430. DOI: https://doi.org/10.1037/0096-3445.134.3.426

Rouder, J. N., Speckman, P. L., Sun, D., Morey, R. D., & **Iverson, G.** (2009). Bayesian t tests for accepting and rejecting the null hypothesis. *Psychonomic Bulletin & Review*, *16*(2), 225–237. DOI: https://doi.org/10.3758/PBR.16.2.225

Russell, J. A., & **Mehrabian, A.** (1977). Evidence for a three-factor theory of emotions. *Journal of Research in Personality*, *11*(3), 273–294. DOI: https://doi.org/10.1016/0092-6566(77)90037-X

Scherer, L. D., & **Lambert, A. J.** (2009). Contrast effects in priming paradigms: Implications for theory and research on implicit attitudes. *Journal of Personality and Social Psychology*, *97*(3), 383–403. DOI: https://doi.org/10.1037/a0015844

Schwarz, N. (2007). Attitude construction: Evaluation in context. *Social Cognition*, *25*(5), 638–656. DOI: https://doi.org/10.1521/soco.2007.25.5.638

Smith, E. R. (1996). What do connectionism and social psychology offer each other? *Journal of Personality and Social Psychology, 70*(5), 893–912. DOI: https://doi.org/10.1037/0022-3514.70.5.893

Smith, L. B., & **Sera, M. D.** (1992). A developmental analysis of the polar structure of dimensions. *Cognitive Psychology*, *24*(1), 99–142. DOI: https://doi.org/10.1016/0010-0285(92)90004-L

Spence, C. (2011). Crossmodal correspondences: A tutorial review. *Attention, Perception, & Psychophysics*, *73*(4), 971–995. DOI: https://doi.org/10.3758/s13414-010-0073-7

Spence, C., & **Deroy, O.** (2013). How automatic are crossmodal correspondences? *Consciousness and Cognition, 22*(1), 245–260. DOI: https://doi.org/10.1016/j.concog.2012.12.006

Spruyt, A., De Houwer, J., Hermans, D., & **Eelen, P.** (2007). Affective priming of nonaffective semantic categorization responses. *Experimental Psychology*, *54*(1), 44–53. DOI: https://doi.org/10.1027/1618-3169.54.1.44

Stevens, S. S. (1957). On the psychophysical law. *Psychological Review*, *64*(3), 153–181. DOI: https://doi.org/10.1037/h0046162

Teige-Mocigemba, S., Klauer, K. C., & **Sherman, J. W.** (2010). A practical guide to implicit association tests and related tasks. In: Gawronski, B., & Payne, B. K. (Eds.), *Handbook of implicit social cognition: Measurement, theory, and applications*, 117–139. New York: The Guilford Press. DOI: https://doi.org/10.13140/2.1.4889.1845

Tukey, J. W. (1977). *Exploratory data analysis.* Reading, MA: Addison-Wesley.

Valdez, P., & **Mehrabian, A.** (1994). Effects of color on emotions. *Journal of Experimental Psychology: General*, *123*(4), 394–409. DOI: https://doi.org/10.1037/0096-3445.123.4.394

Walker, L., & **Walker, P.** (2016). Cross-sensory mapping of feature values in the size–brightness correspondence can be more relative than absolute. *Journal of Experimental Psychology: Human Perception and Performance, 42*(1), 138–150. DOI: https://doi.org/10.1037/xhp0000128

Walker, P. (2016). Cross-sensory correspondences: A theoretical framework and their relevance to music. *Psychomusicology: Music, Mind, and Brain, 26*(2), 103–116. DOI: https://doi.org/10.1037/pmu0000130

Walker, P., & **Walker, L.** (2012). Size–brightness correspondence: Crosstalk and congruity among dimensions of connotative meaning. *Attention,* *Perception, & Psychophysics*, *74*(6), 1226–1240. DOI: https://doi.org/10.3758/s13414-012-0297-9

Walker, P., Walker, L., & **Francis, B.** (2015). The size-brightness correspondence: evidence for crosstalk among aligned conceptual feature dimensions. *Attention, Perception, & Psychophysics*, *77*(8), 2694–2710. DOI: https://doi.org/10.3758/s13414-012-0297-9

Walsh, V. (2003). A theory of magnitude: common cortical metrics of time, space and quantity. *Trends in Cognitive Sciences*, *7*(11), 483–488. DOI: https://doi.org/10.1016/j.tics.2003.09.002

Wilcox, R. R. (2012). *Introduction to robust estimation and hypothesis testing*. Amsterdam; Boston: Academic Press.

Wilcox, R. R., & **Tian, T. S.** (2011). Measuring effect size: a robust heteroscedastic approach for two or more groups. *Journal of Applied Statistics*, *38*(7), 1359–1368. DOI: https://doi.org/10.1080/02664763.2010.498507

Willners, C., & **Paradis, C.** (2010). Swedish opposites – a multi-method approach to antonym canonicity. In: Storjohann, P. (Ed.), *Lexical-semantic relations from theoretical and practical perspectives.* (Vol. Lingvisticæ Investigationes Supplementa). Amsterdam; Philadelphia: John Benjamins Publishing Company. http://lup.lub.lu.se/record/1504488. DOI: https://doi.org/10.1075/lis.28.04wil

Woods, A. T., Spence, C., Butcher, N., & **Deroy, O.** (2013). Fast lemons and sour boulders: Testing crossmodal correspondences using an internet-based testing methodology. *i-Perception, 4*(6), 365–379. DOI: https://doi.org/10.1068/i0586

Peer review comments
The author(s) of this paper chose the Open Review option, and the peer review comments are available at: http://doi.org/10.1525/collabra.110.pr

How to cite this article: Schietecat, A. C., Lakens, D., IJsselsteijn, W. A., & de Kort, Y. A. W. (2018). Predicting Context-Dependent Cross-Modal Associations with Dimension-Specific Polarity Attributions Part 1 – Brightness and Aggression. *Collabra: Psychology,* 4(1): 14. DOI: https://doi.org/10.1525/collabra.110

Editor: Nathan Van der Stoep

Senior Editor: Rolf Zwaan

Submitted: 31 August 2017 **Accepted:** 14 April 2018 **Published:** 24 May 2018