The Impact of Perceived Emotions on Early Word Learning

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Declaration

I declare that this thesis is my own work completed solely by myself under the supervision of Professor Gert Westermann, Dr Katherine Twomey and Dr Eugenio Parise, and that it has not been submitted in substantially the same form for the award of a higher degree elsewhere.

Signature

Date

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BF_{01}	Bayes factors for the degree to which the null hypothesis was supported
LMEMs	Linear mixed-effect models
RT1	Retention test 1
RT2	Retention test 2

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Epigraph

故不积跬步 无以至千里 不积小流 无以成江海

—荀子《荀子 劝学》

No steps, no miles; no streams, no oceans.

-Xunzi, *Xunzi Quanxue*

Thesis Abstract

With the background that young word learners learn word-world associations in social interactions full of emotional expressions (Clark, 2016; Fernald et al., 1989) and others' emotional expressions affect individuals' attention allocation and memory during learning (Dolan & Vuilleumier, 2003; Kensinger, 2004; Yiend, 2010), the emotions perceived by individuals influence the learning process and outcome. Although, compared to affectively neutral expressions, infants allocated more attention to emotional vocal and facial expressions (e.g., Cooper & Aslin, 1990; Grossmann et al., 2011) and objects associated with negative emotions (e.g., Carver & Vaccaro, 2007), the impact of perceived emotions on early word learning remains unclear. To address the question, the current work encompasses three eye tracking experiments measuring proportion looking time of 24-, 30- and 36-month-old toddlers and adults when they learned three novel label-object associations respectively in affectively neutral, positive, and negative contexts in a referent selection learning task and when they recognised the new-learned label-object and emotion-object associations in retention testing tasks.

The first experiment (Chapter 2) examined whether the perceived emotions influence adults' and 30-month-old toddlers' learning and retention of label-object and emotion-object associations and compared adults' and toddlers' looking behaviours during learning. Results suggested the recognition of newly learned association revealed the level of memory ability and the outcome of a competition for attention between top-down and bottom-up processing. Adults demonstrated a mature memory ability and top-down control and recognised all the

label-object and emotion-object associations. But toddlers' retention might be interfered with the presence of salient negative distractor.

Based on the findings of the first experiment, the second experiment (Chapter 3) investigated the possibility that the salient negative distractor masked 30-month-olds' retention and explored the implicit impact of negative objects on toddlers' visual attention. After removing the negative distractor from half of a retention task, the 30-month-olds successfully recognised all the label-object associations regardless of the emotions that the objects associated with. Regarding the implicit impact of negative objects, toddlers tended to look to the negative object when it presented, suggesting it captured toddlers' visual attention relative to its neutral and positive counterparts. Thus, a negativity bias was found.

The third experiment (Chapter 4) measured the word learning outcome and retention of emotion-object associations in toddlers of 24-month-old and 36-month-old to further examined the effect perceived emotions on early learning. The older toddlers' word learning was not affected by the perceived emotions while the younger toddlers' word learning was promoted by the perceived negative affect during learning. Both age groups only recognised the negative emotion-object associations, revealing the ability to memorise the association between emotional cues and objects is still developing at the age of 36-month-olds.

Overall, for the toddlers as young as 24-month-old, the perceived negative affect facilitates the learning of label-object associations. But for the toddlers older than 30-month-old, their word learning is not influenced by the perceived emotions. Meanwhile, toddlers' visual attention is interfered with the distractor associated with negative affect, suggesting the negativity bias in terms of visual processing. Additionally, the finding of the impact of negativity bias on toddlers' visual attention raises an issue relating the methodology that the reliability of proportion looking time as an index of retention is undermined when perceptually salient competitors are presented. All in all, the current thesis showed not only how the impact of perceived emotions on early word learning, but also the methodological consideration for the eye tracking word learning experiments.

Chapter 1: Literature Review

1.1 Introduction

Emotion processing is a critical facet of infant development. Infants discriminate different emotional voices and facial expressions within the first year after birth (Grossmann et al., 2010) and start to show understanding of the sophisticated meanings of emotions in the second year of their life (e.g., Hepach & Westermann, 2013; Repacholi & Gopnik, 1997). Meanwhile, word learning is another crucial facet in early development. From simply discriminating linguistic speech from sounds as neonates (Eimas, 1971; Vouloumanos & Werker, 2007) to speaking their first meaningful word at around 12 months (Benedict, 1979), infants absorb sound patterns they hear based on the statistical regularities in their linguistic input. At first, they acquire the most frequently heard nouns, verbs and adjectives and extend the range of those words (Clark, 1995; Saffran et al., 1996). In doing so, infants attend to language that is directed to them, to the objects that are physically and conversationally present, and to language that attracts joint attention between their caregiver and them (Clark, 2016; Tomasello, 2003). Thus, social interaction with others is essential to word learning, and emotional information present in these interactions affects infants' perception and learning of the surrounding world.

Importantly, the emotions perceived by infants affect their attention (e.g., Hoehl et al., 2008), behaviours (Moses et al., 2001; Sorce et al., 1985), and learning (Singh et al., 2004; for a review, see Dolcos et al., 2020; Tyng et al., 2017; Yiend, 2010). When processing emotional information (e.g., pictures and words with emotional connotations, facial expressions), compared to neutral information, adults show, for example, better recognition (e.g., Sharot & Phelps, 2004), stronger brain responses (Breiter et al., 1996), and shorter reaction times (e.g., Öhman et al., 2001). Furthermore, the valence of emotion (positive vs negative) also affects cognitive processing: adults show enhanced cognitive processing of positive relative to negative linguistic information, but this pattern of processing is reversed for pictorial stimuli (Yuan et al., 2019).

Several neuroscience studies have indicated that affective and cognitive processes, in the amygdala-based and hippocampus-based neural system respectively, are integrated with each other (Dolcos et al., 2011; Okon-Singer et al., 2015). Therefore, perceived emotions affect the hippocampus-dependent memory system (Pessoa, 2008), exerting an influence on learning and memory (Doan, 2010). Indeed, emotional information is more likely to be detected and encoded relative to neutral information (Dolan & Vuilleumier, 2003), and emotionally arousing information is likely to be consolidated more effectively than the non-arousing information (Kensinger, 2004), which might increase the likelihood of retrieval of the emotional information (Buchanan, 2007) as evidenced by the fact that the emotional experiences are remembered more vividly than neutral experiences (Berntsen & Rubin, 2002). Moreover, the types of information (e.g., pictures, letter strings) memorised and learned in experimental tasks result in different learning outcomes. For examples, in terms of pictures, when adults saw an affective arousal scene after encoding a neutral face or house, their recognition rate of the face and house was positively linked with the level of arousal of the affective scenes (Adam et al., 2006). In contrast, for letter strings, after learning pseudowords paired with affectively positive, neutral and negative pictures, adults' retention of words was similar across the conditioned affects, and they also recognised the emotionality of positive and negative pseudowords (Fritsch & Kuchinke, 2013; Kuchinke et al., 2015). Overall, the recognition and learning of information are influenced by the emotional contexts in which the information is presented. While there are several studies with adults, the investigation of the effect of perceived emotions on early learning is sparse.

Some studies have reported that infants are attracted by positive auditory signals (e.g., infant directed speech that consists of high-pitched voice, featured as positive affect), while, relative to objects conditioned with positive or neutral affect, they pay more attention to objects conditioned with negative affect (e.g., fear) but avoid playing with these objects (e.g., Cooper & Aslin, 1990; Hoehl & Pauen, 2017; Mumme & Fernald, 2003). However, little research has focused on the impact of emotional information produced by others on infants' learning of words and objects. Specifically, while infants can recognize their names, the labels of objects and the verbs of actions they are familiar with even by nine months of age (Bergelson & Swingley, 2012; Bortfeld et al., 2005; Syrnyk & Meints, 2017), it is unclear how perceived emotions influence young word learners' attention in encoding, retaining, and recognising of newly learned word-world associations.

Therefore, the current research will focus on bridging emotion perception and early word learning in a relatively social context to investigate the possible impact of perceived emotions on toddlers' learning and retention of word-object associations via the lens of attention and memory. The following literature review presents the relevant background and empirical evidence about the potential role of perceived emotions during word learning involving emotional stimuli and linguistic input. It begins by reviewing the theoretical background of the effects of perceived emotions on learning through the perspectives of attention and memory in information processing and retrieval, and then moves to the empirical evidence describing infants' attention towards emotional vocal and facial expressions and emotionally conditioned objects. This is followed by a review of what is currently known about the impact of perceived emotions on word learning in adults and infants. The chapter concludes with an introduction of the word learning paradigm employed in the current research.

1.2 Perceived Emotions and their Effects on Attention

The nature of emotions has been subject to debate for decades (e.g., Adolphs & Andler, 2018; Barrett, 2006, 2017; Ekman, 1999; Kragel & LaBar, 2016; Russell, 2003), with several theories put forward about their origins and functions. *Basic emotion theory* argues that certain emotions, such as fear, happiness, anger, sadness, and disgust, are biologically and physiologically basic, discrete in terms of brain neural networks, and universal in expression across the species when reacting to environmental events (Ekman, 1999; Tracy & Randles, 2011). In contrast to this view, *constructionist theories* suggest that emotions are constructed by individuals' interoceptive sensations such as affect, feelings, and moods, influenced by the activities of parasympathetic nervous system, as well as exteroceptive experiences such as sensory perception, memory of life events and language. In this view, emotions are the consequence of combining activities in domain-general networks of the brain (Barrett, 2017, 2018; Barrett & Satpute, 2013). Although the definition of emotion is controversial, there is still a consensus that “affective phenomena” consist of biological and physiological components and expressions, behaviours and appraisals that describe the relation between individuals and the environment, and influence individuals’ cognition, such as attention and memory (Dolcos et al., 2020).

It is well established that emotions influence learning by affecting attention and memory (Dolcos et al., 2020; Tyng et al., 2017; Yiend, 2010). Research examines not only the impact of emotion on attention and memory in terms of subjective emotional states, such as anxiety, depression, and personal emotional experiences, but also through emotions expressed by others, such as the salience of emotional stimulation (e.g., facial, vocal, body expressions), the detection and retention of natural enemies (e.g., snakes) and learned emotion-object associations (e.g., guns; e.g., Vuilleumier, 2005; Vuilleumier et al., 2003; Yiend, 2010; Öhman et al., 2001). The term, “perceived emotions” in the current work, refers to the latter condition. To specifically discuss the impact of perceived emotions on the learning, the theoretical background of how perceived emotions affect attentional processes and memory will be covered in the following section.

1.2.1 Perceived Emotions and Attentional Processes

A prominent view in the literature holds that in the brain there are two functionally and structurally distinct attentional systems. One is for stimulus-driven, bottom-up attentional processing, and the other for goal-directed, top-down attentional processing (Shulman & Corbetta, 2002). Meanwhile, attention selection, singling out the appropriate information to process from multiple sensory inputs (Johnston, 1986), and sustained attention, maintaining focus on a stimulus at a certain level for a prolonged time (Sarter et al., 2001), involve both bottom-up and top-down attentional processing, which are both affected by perceived emotions (Yiend, 2010). In learning, attentional processes are particularly affected by perceived emotions during information encoding and recognition (Dolan & Vuilleumier, 2003; Kensinger, 2004). For instance, in a study on face processing, activity in the amygdala was enhanced when adults processed fearful and happy faces relative to neutral faces (Breiter et al., 1996), suggesting that affectively positive and negative stimuli are more distinctive than neutral ones and thus attract more attention. This is especially true for stimuli with negative affect, such as unhappy or fearful faces, and fear-relevant objects (e.g., snake), which were detected more quickly than fear-irrelevant objects (e.g., Eastwood et al., 2001, 2003; Hoehl & Striano, 2010b; Vuilleumier, 2005).

Supporting the idea that emotional information can affect attentional processing, when salient emotional stimuli are task irrelevant, they compete with the task relevant stimuli for attention and thus interfere with individuals' selective and sustained attention to the target stimuli (Iordan et al., 2013). Individuals' sustained attention to one object is the outcome of selecting the most significant and relevant stimuli and suppressing the remainders among the multiple sources of inputs (Desimone & Duncan, 1995). This process involves competition between both bottom-up (emotional distractors) and top-down (task-relevant target) attentional processing. For instance, Eastwood et al. (2003) examined the effect of emotional distraction by measuring reaction time and accuracy when adults counted facial features of neutral, positive or negative schematic faces. They found that adults spent more time when counting the features of the negative face than the neutral and positive faces, indicating that the negative schematic faces captured more attention when the adults performed the primary task of counting the features. The study revealed that individuals' performance of task is affected by the perceived negative emotional expressions via a possible bottom-up, stimulus-driven attentional process.

1.2.2 Perceived Emotions and Memory

Perceived emotions not only capture individuals' attention but can also enhance memory (e.g., Hamann, 2001; Kensinger et al., 2007; Taylor et al., 1998). After individuals attend to emotionally arousing information during encoding, activating the amygdala-hippocampus circuit, the information associated with these emotions is further consolidated to form long-lasting memories (McGaugh, 2004; Murty et al., 2010). For example, Kensinger and Corkin (2003) employed a word recognition task to examine whether adults memorized emotionally negative words better than neutral words. Participants first completed a study session in which they rated each word as abstract or concrete. Then, after a 15-minute delay, they were asked to select the words they had encountered in the study session. Results revealed that the participants memorized more negative words than neutral words.

Additionally, Shafer and Dolcos (2012) found that individuals showed better recognition of emotionally negative pictures than neutral ones when the task was attentionally demanding. In a perception task, participants were first asked to determine the orientation (horizontal and vertical) of the pictures, including both emotionally negative and neutral stimuli. Attentional demand was controlled by the presentation duration and the ratio of the vertical to horizontal sides of the pictures. Then, after a 40-minute delay, participants completed a recognition task in which they were asked whether or not a picture was one they had seen before. Behavioural data showed that adults' reaction time was shorter for detecting negative than for neutral pictures. Participants' recognition of negative pictures was better than neutral ones in the high attentional demand condition (when those pictures were presented for a shorter time duration and the ratio of the vertical to horizontal sides was low in the perception task), suggesting the memory recognition benefitted from the negative emotionality perceived during the demanding experimental task.

Overall, attentional processing of perceived emotional information can be automatic but can also be modulated by task requirement via the top-down control (Shafer & Dolcos 2012; Vuilleumier, 2005). Perceived emotions can enhance memory but also impair task performance through interference (e.g., Eastwood, 2003). The findings described above are based on research in healthy adult populations. The following sections will discuss what is currently known about the impact of perceived emotions on attention in early development, and specifically in word learning.

1.3 The Impact of Perceived Emotions on Attention in Early Development

Early in development, infants process affective vocal and facial expressions differently from neutral expressions (e.g., Blasi et al., 2011; Grossmann et al., 2010). For example, neonates prefer to look at stimuli accompanied by infant-directed speech, which features an affectively positive prosody with higher pitch, over stimuli accompanied by adult-directed speech (Cooper & Aslin, 1990); and seven-month-old infants look longer to fearful than to happy faces in a visual preference task (Kotsoni et al., 2001). These and other findings indicate that infants can discriminate different emotional features (for a review, see Walker-Andrews, 1997), such as more widely opened eyes or a smaller mouth on the fearful than on happy faces (e.g., Kotsoni et al., 2001), and high and low pitches in emotional vocal stimuli (e.g., Walker-Andrews & Grolnick, 1983). This ability to discriminate emotional information may help infants to infer others' intentions and desire (Tomasello, 2001; Whiten, 1991), or to associate different emotions with co-occurring events, such as others' reactions and expressive language (Barrett, 2018). As a result, infants acquire knowledge that is relevant to a particular emotion, which is specific to the domain in which they experienced the emotion, for instance, from 10- to 14-month-old of age, they gradually learn that person showing cheerful expressions is more likely to touch toy gently instead of thumping it (Hepach & Westermann, 2013). During the acquisition of emotion-relevant knowledge, infants' attention is affected by the emotional information. In the following, I will review infants' attentional responses towards emotional vocal and visual stimulation.

1.3.1 The Impact of Perceived Emotions on Attention towards Vocal Stimuli

At the beginning of life, neonates first allocate their attention to a familiar stimulus, and then to novel stimuli after they have habituated to the familiar stimulus (Rose et al., 1982). In terms of vocal stimuli, even newborns show a preference to the human voice relative to non-human auditory stimuli (e.g., Ecklund-Flores & Turkewitz, 1996) and to their own mother's voice over other newborns' mothers' voices, suggesting that pre-natal experience affects post-natal perception (DeCasper & Fifer, 1980). Regarding infants' response to vocal expression of different emotions, Mastropieri and Turkewitz (1999) reported that neonates showed increased eye opening when they heard their native language spoken in happy relative to angry prosody, indicating that even hours-old neonates are able to detect the differences between different emotional prosody. Furthermore, infants aged 3 and 5 months detected changes in prosody between sad and happy speech and showed different attentional processing: Walker-Andrews and Grolnick (1983) habituated 3- and 5-month-old infants to either a sad or happy voice with corresponding static facial expressions, and then measured the infants' looking time to the same static expression after the voice was changed from sad to happy or vice versa. Three-month-old infants looked longer to the face when hearing a change in the speech from sad to happy, but not from happy to sad, whereas 5-month-old infants dishabituated to the changes in the speech for both directions. These findings suggest that for 3-month-old infants, happy vocal expression of higher pitch and more variations attracted their attention more than the sad vocal expression of lower pitch and less variations when a change of tone happened; but for 5-month-old, it was the change per se that attracted their attention but not the vocal expression, indicating a development of attentional disengagement between 3 and 5 months of age.

In the first year of life, relative to facial expressions alone, infants are more attentive to vocal expressions and bimodal facial and vocal expressions. Mumme et al. (1996) employed a social referencing paradigm in which they observed infants' reaction to a novel toy after seeing or hearing their mothers' neutral, happy and fearful facial or vocal expressions. The 12-month-olds looked to their mother longer, showed less toy proximity and more negative affect in the fearful voice-only condition when their mothers had their back turned to them, but they did not behave differently in the face-only condition. Additionally, in a visual cliff task, 12-months-olds received positive facial-only, vocal-only and facial plus vocal expressions from their mothers. Only the infants in the vocal-only and facial plus vocal expressions crossed the cliff faster and looked longer to their mother than in the facial-only condition (Vaish & Striano, 2004). Therefore, compared with facial expressions, vocal expressions appear to be more potent in grabbing 12-month-old infants' attention and regulating their behaviours. Overall, infants are able to discriminate emotions in the auditory modality and actively encode emotional speech according to the potential affective functions of vocal expressions from the earliest stages of development.

1.3.2 The Impact of Perceived Emotions on Attention towards Visual Stimuli

As well as being able to discriminate vocal emotion expressions, infants discriminate visual emotion expressions in the form of different facial expressions shortly after birth. For example, after habituating to a facial expression (e.g., a happy face), three- to four-month-old infants discriminate between angry or surprised faces and happy faces, indexed by longer looking to a new facial expression (Barrera & Maurer, 1981; Young-Browne et al., 1977). Interestingly, infants show a change in attention allocation from looking longer at happy faces at five months of age to looking longer at fearful faces at seven months (Grossmann et al., 2011; Nelson & Dolgin, 1985; Peltola et al., 2009). This change of attention allocation from positive to negative expressions, on the one hand, could be due to the development of locomotor ability in infants (Leppänen & Nelson, 2012; Vaish et al., 2008). After being able to crawl and walk, on the one hand, caregivers may express more anger or fear trying to control their infants' behaviours (Campos et al., 1992); on the other hand, infants increasingly refer to others' emotional responses when they encounter novel or ambiguous situations to assess the danger or safety of a situation (e.g., Sorce et al., 1985; Striano & Rochat, 2000). Thus, beyond enabling infants to assess a novel situation, when adults display different emotional expressions towards a novel object, infants' attention to the novel object also varies accordingly.

Hoehl and colleagues conducted a series of studies in which they recorded three-month-old infants' event related potential (ERP) responses to an adult female looking towards unfamiliar objects with either a fearful, happy, or neutral facial expression on a computer screen (Hoehl et al, 2008; Hoehl & Striano, 2010 a,b). Hoehl et al. (2008) examined how infants reacted to one fearful-related and one neutral-related object, but critically without also presenting emotional faces. Results demonstrated that three-month-old infants allocated more attention to the fearful-related object than the neutral related objects. Hoehl and Striano (2010a) employed the same paradigm to examine three-month-old infants' ERP response to novel objects after observing a female showing positive and neutral expression towards the objects. They found a similar Nc (Negative-central; a component related to attention) response when infants saw the positive-related object and the neutral-related one. Together these studies suggested that when processing emotion-associated objects three-month-old infants allocated more attention to the emotionally negative object but not the positive and neutral ones.

In another follow-up study, Hoehl and Striano tested three-, six- and nine-month-old infants using a similar procedure with a fearful/neutral contrast (Hoehl & Striano, 2010b). They found a stronger Nc response to the fearful-related object compared to the neutral-related object in three- and six-month-old infants. In contrast, the nine-month-olds showed the opposite response with a stronger Nc to the neutral associated objects. The authors suggested that the different attention allocation between the younger and the older infants could be explained by the development of executive attention during the first year of life through development of the anterior cingulate (Posner & Petersen, 1990; Posner & Rothbart, 1998; Stifter & Braungart, 1995). Specifically, the three- and six-month-olds could have shown a more automatic and uncontrolled attention to the salient objects based on an adult's emotional expression, while the nine-month-olds' response might show more elaborate attention control resulting in attenuated attention to the emotionally negative object.

However, enhanced attention towards emotionally negatively conditioned objects was found in 12-month-olds when the emotions towards a novel toy were expressed by the infants' own mothers (Carver & Vaccaro, 2007). In this study, infants observed their caregivers interacting with three objects in happy, disgusted, and neutral affect, respectively. After a 20-minute delay, infants' ERP responses to the objects were measured. The 12-month-old infants showed an enhanced Nc response to negatively relative to positively and neutrally conditioned objects. The difference between this result and that for the 9-month-olds in Hoehl and Striano's study (2010b) might be due to the possibility that the information conveyed by caregivers attracts infants' attention more than a stranger (Barry-Anwar et al., 2017) and that early learning is more effective in real life than on a screen (Judy et al., 2010). Therefore, the 12-month-olds, who observed their mothers directing negative emotions to a novel object in the real world, might have encoded the object more deeply. Combined with the findings above, attention allocation is influenced by both intrinsic factors, such as the development of the neural networks supporting attention, and external factors, such as the identity of the informants, experimental paradigms, and critically, others' emotional information.

In addition to the ERP findings, in the field of visual attention, an eye tracking study found that children distributed attention differently depending on perceived emotions. In Flom and Johnson's study (2011), 12-month-old children watched videos to habituate to a novel toy. In a 'happy' condition, an experimenter looked at the toy while expressing facially and vocally positive affect, while in a 'disgust' condition, a disgust affective expression was conveyed toward the toy. Following habituation, children's looking preference to happy and disgust-habituated toys was measured after a five-minute, one-day and one-month delay. Infants looked longer to the toy paired with positive affect than the toy paired with negative affect after the five-minute and one-day but not the one-month delay. Other studies have found that infants even regulate their own behaviours according to adults' emotional reaction towards an object. For instance, Mumme and Fernald (2003) found that 12-month-olds displayed more negative affect and avoided playing with a toy after watching an actress showing a negative expression towards the toy. Findings of both studies indicated that young children associated the perceived negative emotion with the toy and adjusted their own behaviours accordingly.

Overall, when processing visual stimuli, infants associate the emotions displayed by adults with the corresponding objects, encoding the information of both the perceived motions and the visual stimuli. Moreover, these perceived emotions affect their attention allocation when processing the relevant information, manifesting as enhanced attention towards negatively associated object on the neural level while showing a visual attention preference for the positive object at least in the first year of life.

1.4 The Impact of Perceived Emotions on Word Learning

As reviewed above, perceived emotions affect infants' attention on both visual and neural levels, indicating an impact of emotions on information encoding, maintenance and recognition (Tyng et al., 2017). Specifically, the effect that emotions influence attention in turns affects learning and memory. During the process of learning and recognition, compared with emotionally neutral stimuli, emotionally salient stimuli attract more attention, resulting in enhanced perceptual processing and accurate recognition (Sharot & Phelps, 2004; Vuilleumier, 2005). Regarding the perception of words, interestingly, as symbolic units which bear no emotional meanings per se, words evoke an attentional bias in adults (e.g., Schindler & Kissler, 2016), suggesting the emotionality is processed as an integral attribute of words. Namely, there are words such as *love*, *hate*, and *anger*, which reflect an abstract combination of affective experiences. Further, words can obtain emotionality, such as pseudowords learned in emotion associative learning tasks (Fritsch & Kuchinke, 2013; Kuchinke et al., 2015).

Regarding early word learning, young word learners need to integrate and evaluate diverse information they perceive to learn word-world associations (Monaghan et al., 2018). As proposed by the emergentist coalition model (Hollich et al., 2000), they are sensitive to multiple cues, specifically, attentional, linguistic and social cues. For attentional cues, the most salient, novel, attention-grabbing objects are likely to be associated with sounds or novel labels when children see the objects and hear the auditory stimuli simultaneously (e.g., Gogate & Bahrick, 1998; Golinkoff & et al., 1992). For linguistic cues, for example, prosody facilitates children to segment linguistic units (e.g., Saffran et al., 1996), and grammatical information (e.g., *the blick* for an object, *blicking* for an action, Echols, 1998), influences the way children associate words with referents. Social cues, such as others' eye gaze and pointing (e.g., Briganti & Cohen, 2011; Tsuji et al., 2020), facilitate children to identify the referents of words. Moreover, with development, word learners evaluate these inputs and weigh the importance of them in service to the learning of label-object associations, from attending to the perceptual salient cues to relying on others' social cues when identifying referents (Hollich et al., 2000).

Importantly, infants learn label-object associations in social interactions full of emotional expressions (Clark, 2016; Fernald et al., 1989). Thus, they must process emotions, language and objects simultaneously and associate these different cues from the outset, which raises the possibility that their attention is affected by the associations being formed. However, how young word learners process emotional information during the learning of label-object associations and the resulting effect on their attention allocation remains largely unknown. The following section will discuss the handful of studies with adults and children that have explored the learning of novel linguistic information under the perception of emotions at the same time.

1.4.1 The Impact of Perceived Emotions on Word Learning in Adults

Two studies with adults have shed some light on the learning of pseudowords associated with emotions (Fritsch & Kuchinke, 2013; Kuchinke et al., 2015). In these studies, participants first learned a written pseudoword associated with emotionally neutral, positive and negative pictures over five days. Then, they were tested in a lexical decision task to examine their retention of the pseudowords while ERP was measured. They also completed a task to rate the emotionality of the pseudowords. Results indicated similar retention for all words, but words associated with positive and negative pictures were rated higher on emotionality and elicited greater neural responses compared to neutral words. These results suggested that word learning was not affected by the emotions associated with the words, but that the emotionality of the words could be learned.

A related functional magnetic resonance imaging (fMRI) study partially illustrated the cognitive process of recalling label-object associations learned in situations where emotional expressions were present (Tsukiura et al., 2003). In the study, participants first encoded two groups of name-face pairs, one group with positive facial expressions and the other with neutral facial expressions. Then, after a five-minute and a two-week delay, adults' retention of name-face associations was measured by seeing the faces one at a time and being asked to choose the target name from two options. The results revealed that adults retained around 75% of the 48 name-face associations after the five-minute delay, and more than half of the associations after a two-week delay regardless of facial expressions. The fMRI showed that in the five-minute delay test, adults' anterior bilateral temporal lobe was activated when they recognised the name-face associations successfully, but only the left anterior temporal lobe was still activated in the two-week delay test. Additionally, the adults' left peri-amygdaloid area was activated when processing the positive faces but not the neutral ones at both times. These findings indicated that the neural pathway for retrieving names of faces is different over time and different from the perception of the facial expression alone, suggesting that adults showed specific attentional patterns according to the features of information required during recognition, but that the retrieval of linguistic information and the perception of emotions was independent in this study.

Overall, in adults, language and emotional information are processed differently. Adults learn the emotionality of a pseudoword depending on the emotionality of accompanying pictures, while the recognition of learned pseudowords is independent of their emotionality (Fritsch & Kuchinke, 2013; Kuchinke et al., 2015). Similarly, after learning name-face associations by perceiving positive and neutral facial expressions, adults retain the names regardless of the facial expressions (Tsukiura et al., 2003).

1.4.2 The Impact of Perceived Emotions on Early Word Learning

Apart from studies showing that infant-directed speech featuring positive emotional expression and high-pitched voice facilitates infants' word segmentation and learning (Cooper & Aslin, 1994; Thiessen et al., 2005), little research on early language development has focused on the impact of perceived emotions on learning performance. The following two experiments partially addressed this issue and suggested that the learning of novel words and label-object associations is affected by the perceived emotions in terms of two perspectives: a low-level perceptual difference between emotional vocalisations, and a high-level conceptual understanding of different emotions.

One study conducted by Singh and colleagues (2004) showed that emotionally positive vocalizations affect infants' recognition of words. They first familiarised seven- and ten-month-old infants with both emotionally positive and neutral spoken unfamiliar words. Then, they employed a head-turn preference procedure to test whether infants could recognize the familiarised words in fluent speech when spoken in positive and neutral affect. At test, half of the participants heard positive and another half neutral speech. The authors found that both age groups failed to recognise the neutrally familiarised words in a positive spoken affect but recognized them in the neutral spoken manner. Further, whereas ten-month-olds recognised the positively familiarised words in both positive and neutral affect, seven-month-olds recognised them only in positive spoken manner. These results suggest that infants do not readily generalise word recognition across emotional contexts, with only 10-month-olds being able to do so and only for positively familiarised words, which could benefit from the sound pattern of positive vocalisation, facilitating infants' word learning (Cooper & Aslin, 1994; Thiessen et al., 2005).

Another word learning study demonstrated that others' emotional expressions can affect toddlers' judgment of learned target label-object associations, reflecting the understanding of different emotional expressions in toddlers of 18 months (Tomasello et al., 1996). In this study, an experimenter told 18-month-old toddlers that they would search for a specific object (*"let's find the gazzer"*) among four novel objects. During searching, she showed a negative, disappointed expression when she found the distractor but showed a positive cheerful expression when she found the target; in a control condition, she found target and labelled the target in a neutral affect. In a subsequent test, the experimenter asked toddlers to put the *gazzer* on a tray. They found that only 2 out of 16 toddlers in the control group chose the *gazzer*, but 10 out of 16 toddlers were able to identify the *gazzer* at test, suggesting that the experimenter's positive expression led 18-month-old toddlers to associate the label with the target object. This finding suggests that 18-month-olds were able to employ others' emotions as valid information to achieve the learning of label-object associations: the toddlers understood that the positive emotional expression indicated that the experimenter succeeded in finding the referent of *gazzer* whereas the negative expression indicated she failed.

Overall, as described in the empirical evidence from both adults and infants, individuals can learn associations between words, objects and emotions. These learned associations affect attentional processing and memory retrieval at different stages of learning. During the process of word learning, emotionally salient stimuli attract more attention than neutral stimuli and toddlers can identify target label-object association depending on the valence of emotion. During recognition, adults process emotional and linguistic information independently from each other (e.g., Tsukiura et al. 2003), and infants' word recognition was promoted by happy vocalisation (Singh et al., 2004) and their learning of label-object association was directed by the perceived positive and negative expressions (Tomasello et al., 1996). However, the impact of perceived emotions on the level of attention and memory during the learning of label-object associations is still unclear; specifically, how young word learners allocate their attention when perceiving different emotions during learning and recognition of the learned label-object associations is unknown. To examine these questions, the current project was designed. The next section will introduce the word learning paradigm used in this thesis.

1.5 Word Learning Task: Referent Selection & Retention Paradigm

To integrate elements of perceived emotions, language and objects in a word learning task, the experimental design should embed external emotional information in the process of learning novel label-object associations. To examine the effect of perceived emotions on word learning outcomes and whether perceived emotions are attributed to the objects by participants, the design should separate the impact of perceived emotions and newly learned labels on the retrieval of label-object associations when recognition is tested. These requirements can be fulfilled by the *referent selection* and *retention* paradigm (e.g., Axelsson & Horst, 2014; Twomey et al., 2017). This paradigm consists of a learning phase known as *referent selection*, followed by a recognition test, known as *retention*. In the referent selection phase, a set of objects is presented side-by-side live or on a screen, typically consisting of two familiar and one novel object. A novel label is then given, e.g., 'Look at the *toma'*, with the expectation that infants select or look to the novel object as the referent (e.g., Twomey et al., 2017). Typically, several novel label-object pairs (3-4) are taught in this manner in a single session. In the retention test, the novel objects learned in the referent selection phase are then presented side-by-side to children, and they are asked to get, or look at, one of the objects by the label attached to it, e.g., "*Can you give me the toma?*" To investigate how young word learners allocate their attention during this task, eye movements can be measured by using an eye tracker (e.g., Hilton et al., 2019).

The referent selection/retention word learning paradigm has been reported in the literature as a reliable design to elicit word learning in young children aged from 18 to 36 months old (e.g., Axelsson & Horst, 2014; Horst & Samuelson, 2008; Kucker et al., 2018; Twomey et al., 2016). Results have shown, for example, that toddlers' word learning performance is influenced by contextual repetition (Axelsson & Horst, 2014), variability of exemplars during training (Twomey et al., 2014), the number of competitors during learning (Horst et al., 2010), background variability (Twomey et al., 2017) and participants' level of shyness (Hilton & Westermann, 2017). However, the impact of perceived emotions on the learning of novel label-object association remains unexplored.

Additionally, the evidence indicated that pre-schoolers aged 36 to 42 months were able to learn and recognise novel label-object associations better when they were asked to infer which object was the referent of the novel label than when they were directly told the label of the referent by the experimenter (Zosh et al., 2013). Thus, the referent selection/retention paradigm effectively supports children's independent learning of the perceived emotions and the label-object associations because the paradigm requires children to locate the target label-object association actively instead of being instructed directly and learning passively. Furthermore, the screen-based version of this paradigm with eye tracking (Hilton et al., 2019; Twomey et al., 2017) enables us to obtain a fine-grained view of young children's attentional processes when learning novel label-object associations while objects are labelled in different emotional affect, as well as of their retention of these newly learned associations. Thus, the studies reported in this thesis used this referent selection/retention paradigm combined with eye tracking as the optimal design to address the research question.

Additionally, to unify the terminology of the cognitive processes involved in the referent selection/retention paradigm, we define the terminology in accordance with the empirical evidence reviewed above (e.g., Tomasello et al., 1996; Tsukiura et al., 2003) and the previous word learning studies employing the same paradigm (e.g., Hilton et al., 2019; Twomey et al., 2017). The process of associating novel labels/perceived emotions to novel objects in the referent selection part is defined as *learning* label-object/emotion-object associations (Hilton et al., 2019; Twomey et al., 2017); the process of successfully recognising and pointing to the target associations in the retention phases based on the measurement of learning outcome is defined as the *retention* of newly learned associations (Tomasello et al., 1996; Tsukiura et al., 2003).

1.6 Chapter Organization

The rest of this thesis is organized as follows: First, Chapter Two addresses the question of whether perceived emotions affect word learning and retention in adults and 30-month-old toddlers. Second, based on the findings of Chapter Two, Chapter Three illustrates the impact of salient distractors on visual attention and their resulting effects on toddlers' performance during retention. Third, Chapter Four examines the possible developmental change of top-down attentional processing during retention in 24-month-old and 36-month-old toddlers.

Finally, Chapter Five provides a general discussion of the experimental work, putting the results in a wider context and pointing to future work.

Chapter 2: How Perceived Emotions Affect Learning and Retention of Label-Object Associations in Adults and Toddlers

2.1 Introduction

As described in the literature review, word learners, including both adults and infants, integrate multiple cues when learning novel words. Adults can recognise newly learned pseudowords and learn the emotionality associated with them but are not influenced by the emotionality of words during recognition (Fritsch & Kuchinke, 2013; Kuchinke et al., 2015; Tsukiura et al., 2003); while infants continuously integrate and evaluate attentional, linguistic and social cues during word learning in the course of development (Hollich et al., 2000). Therefore, infants' learning of word-world associations is affected more by the perceived emotions and less mature than adults', at least, in terms of recognition, especially when the associations are conveyed in a social context full of emotional information (Clark, 2016; Tomasello, 2003).

To learn the label-object association in the social context full of emotions, young word learners need to integrate the labels, objects, and the perceived emotions. In the object processing tasks, others' emotions affect infants' attention allocation. Flom and Johnson (2011) reported that after habituating to an actress directing happy and disgusted expressions towards two novel objects, 12-month-old infants looked longer at the object paired with a happy expression in a preferential looking task, both after a five-minute delay and the day following habituation. In contrast, Carver and Vaccaro (2007) demonstrated that 12-month-old infants showed an enhanced event-related potential (ERP) response to negatively conditioned objects. In this study, infants observed their caregivers interacting with three objects in an emotionally positive (happy), negative (disgusted), and neutral manner, respectively. After a 20-minute delay, infants' ERP responses to the objects were measured. A larger Nc was found when infants saw the object associated with the negative emotion compared to the objects associated with positive or neutral emotions. A similar effect was also found in six-month-old infants, who showed a stronger Nc for objects which they had observed alongside a fearful face compared to a neutral face (Hoehl & Striano, 2010b). Overall, therefore, after being familiarised with objects paired with emotions, infants' neural responses are enhanced when processing negatively conditioned objects, but their looking preference is towards positively conditioned objects.

Beyond affecting infants' processing of objects associated with emotions, as illustrated in Chapter 1, the perceived positive vocalisations have also been shown to facilitate infants in generalising words spoken in different affective speech relative to neutral speech (Singh et al., 2004), suggesting that the speech contour in positive prosody facilitates infants' processing of linguistic information during word segmentation (Thiessen et al., 2005). Relatedly, toddlers learned novel label-object associations when the experimenter showed positive expressions when identifying the referent of the novel label but negative expressions when identifying the distractors. However, infants failed to learn the associations when the experimenter displayed a neutral expression. Overall, therefore, the perceptual differences of affective prosody affect infants' recognition of words (e.g., Singh et al., 2004), and toddlers understand the conceptual implications of positive and negative expressions in this task

(Tomasello et al., 1996). Moreover, based on the findings from both behavioural and neural research with infants, emotionally conditioned stimuli are allocated more attention than neutral stimuli, which may promote the learning process and influence learning outcomes. Specifically, differences in attention allocation due to differences in perceived emotions may lead to differences in the processing of visual and vocal information. Nevertheless, although emotional information is ubiquitous in the language young children encounter (Clark, 2016; Foolen, 2012; Tomasello, 2003) and despite evidence that emotions influence early word learning (e.g., Sign et al., 2004; Tomasello et al., 1996), it remains unclear how the perceived emotional information affects toddlers' learning of label-object associations. Additionally, even though studies with adults have revealed that adults' word learning was not affected by the emotions associated with the words, and that the emotionality of the words could be learned (Fritsch & Kuchinke, 2013; Kuchinke et al., 2015), adults' learning and recognition of label-object association under emotional conditions has not been explored before.

To investigate these questions in both adults and children, here we presented participants with a word learning task in which object labels were spoken in different emotional affect and examined children's and adults' word learning performance. In an initial referent selection phase, we presented toddlers with an array of three objects on a computer screen, two familiar and one novel. In a departure from the typical procedure in such tasks (e.g., Hilton et al., 2019; Twomey et al., 2017), which seek to minimise social cues, in the current study an actress also appeared on the screen and labelled the objects using neutral, positive (happy), or negative (disgusted) affect. Afterwards, we tested short-term (after 5 minutes) and long-term (after one day) retention by measuring both toddlers' and adults' looking preference and pointing responses to target objects. To tease apart the roles of perceived emotional prosodies and language in word learning, we included both label and no-label trials in the retention phases. The label trials examined the retention of novel label-object associations, while the no-label trials tested whether participants had associated objects with the affect used in training. Meanwhile, because 24-month-olds fail to retain any novel label-object associations in either in-person or screen-based task after learning in a typical referent selection task (e.g., Horst & Samuelson, 2008; Hilton et al., 2019), but 30-month-olds retained the novel associations (Horst et al., 2010) and 36-month-olds robustly retain novel associations even in a challenging referent selection task with novel competitors (Axelsson & Horst, 2014), we selected 30-month-olds with aim that they should demonstrate variation in retention of novel label-object associations in the current design, thus avoiding celling or floor effects.

Based on previous findings that infants over seven months old allocate more attention to objects associated with negative affect (Hoehl, 2014) and better generalize positive vocalizations compared with neutral affect (Sign et al., 2004), we hypothesised that, compared to novel label-object associations delivered in neutral affect, toddlers would better retain labels delivered in positive and, in particular, negative affect, indicated by greater proportion looking or more pointing to targets in the retention phases. We also expected toddlers to associate positive and negative affect with the corresponding objects during retention tests. For adults, we hypothesised that they would retain all the label-object associations and link all the affective cues with corresponding novel objects. In addition, we also analyse toddlers' and adults' looking behaviours based on labelling affect in the referent selection to explore the possible developmental difference of emotional information processing during learning phase.

2.2 Method

2.2.1 Participants

The adult group consisted of 27 British monolingual English-speaking adults (18 female, range = 20–62 years old, *mean* = 28.56 years old, *SD* = 10.74 years). An additional three adults were excluded due to non-native speaker (1) and poor calibration (2). The toddler group consisted of 38 29- to 31-month-old typically developing British monolingual English-learning toddlers (16 girls, *M* = 926.95 days, *SD* = 23.00 days; range = 883–963 days old). An additional 13 toddlers were excluded from analyses for failure to remain on the caregiver's lap (7); caregiver intervention (3); eye tracker error (2); and experimenter error (1). Toddlers' mean productive vocabulary was 353.27 (*SD* = 57.89, range = 164 – 412). Adult participants and caregivers gave consent to participate and received travel reimbursement. Toddlers were given a story book for taking part.

2.2.2 Stimuli and Design

Six known objects were selected because their labels are familiar to two-year-old toddlers (Fenson et al., 1994). Known objects consisted of photographic images of an apple, a ball, a banana, a car, a cup and a flower. Three novel objects (see Figure 2.1) and three two-syllable nonwords (*coodle*, *bosa* and *teebu*) were selected from the NOUN online database of objects and labels unfamiliar to toddlers of this age (Horst & Hout, 2016). All objects were approximately the same size (Table 2.1). Video recordings of an actress labelling the objects were recorded on an iPhone SE, which was found to provide higher quality recordings than a dedicated video camera. Video stimuli combining the video recordings and the objects were generated in Microsoft PowerPoint 2016 and converted into .wmv format. Video stimuli were displayed on a dark grey background (R = 45, G = 43, B = 37) and consisted of five types of videos: engagement, warm-up, referent selection, reengagement and retention (see Figure 2.2 and 2.3; video examples:

https://osf.io/72kps/?view_only=1bde7885369a4e94afebecaee44c73b6).

Figure 2.1

Novel objects and labels

Table 2.1

Size of Object Pictures and Time Course of Video Stimuli in Warm up and Referent Selection Phases

Phases Type	Target Stimuli (pixel)	Affect Types	Trial Length(s)	1st label onset	2nd label onset	3rd label onset
Warm up	apple (202 × 202)	Neutral	15.00	6.80	8.40	10.20
	ball (192 × 189)		15.50	6.60	8.20	10.00
	banana (242 × 196)		16.00	7.00	8.60	10.40
	car (245 × 198)		15.00	6.90	8.50	10.20
	cup (167 × 207)		16.00	7.20	8.80	10.60
	flower (211 × 208)		15.50	6700	8.40	10.20
Referent Selection	bosa (241 × 201)	Neutral	15.50	6.70	8.40	10.10
		Positive	17.50	7.35	9.30	11.40
		Negative	20.00	8.15	10.40	12.75
	coodle (191 × 149)	Neutral	16.00	6.90	8.40	10.15
		Positive	18.50	7.00	9.10	11.20
		Negative	20.00	7.80	10.10	13.10
	teebu (268 × 211)	Neutral	15.50	6.70	8.30	10.10
		Positive	19.00	7.40	9.55	11.75
		Negative	21.00	8.05	10.50	13.20

Note. Label onsets (s) were counted from the trial onset.

Engagement Stimuli. In a six-second engagement video, the actress, shown at the top centre of the screen, smiled and said *Hello! Let's play a game! Can you find what I am asking for?* in child-directed speech in positive affect.

Warm-up Stimuli. Two warm-up trials were designed to familiarize toddlers with the experimental procedure. The same actress appeared at the top centre of the screen and three known objects appeared at the bottom left, central and right positions (e.g., *banana -cup -flower*). The positions of known objects were counterbalanced across participants. At the beginning of the trial, the actress turned her head to look at the three objects one by one with neutral affect, in silence. Then she looked forward and labelled one of the objects (e.g., *Can you find the* [*banana*]*? Look at the* [*banana*]! *Where is the* [*banana*]*?*). Afterwards, toddlers received ostensive feedback: the actress looked at and labelled the target object in a neutral, friendly manner: *Look! There is the* [*banana*], during which the target object (e.g., *banana*) increased in size.

Referent Selection Phase. The referent selection phase consisted of three blocks in which novel targets were labelled in either neutral, positive or negative affect, and all familiar targets were named in neutral affect. Each block consisted of five trials in which the same novel object and two familiar objects were presented. Sets for each block were *coodle-flower-ball*, *teebu-car-banana* and *bosa-apple-cup* (see Figure 2.2). Each familiar object served as the target object once (known trials) and each novel object served as the target three times per block (novel trials). Ostensive feedback was only given when novel objects were targets in the referent selection phase to facilitate retention (Axelsson et al., 2012).

Block order and the horizontal position of objects in each trial were counterbalanced across participants. Trial order was pseudorandomised within each block with the constraint that the same trial types (known, novel) did not occur more than twice in succession. The first block was assigned neutral affect as a baseline for all participants. The order of positive and negative affect was counterbalanced across toddlers in the second and third blocks. Because the procedure and manner of the actress in neutral trials was identical to that in the warm-up trials, only positive and negative trials are described in detail.

Positive Trials. On positive trials, the actress first looked at the three objects one by one with an emotionally positive (happy) expression: she leaned her body forward with mouth open, eyebrows raised and looked at all objects happily in silence. Then, she looked ahead and labelled the novel objects in a cheerful voice (e.g., *Can you find the* [*bosa*]*? Look at the* [*bosa*]! *Where is the* [*bosa*]*?*). At the end of the trial, with a happy facial expression, she leaned her body towards the target object with a happy interjection (e.g., *Wow! Look! There is the* [*bosa*]!), during which the target increased in size.

Negative Trials. On negative trials, the actress first looked at the three objects one by one with an emotionally negative (disgusted) expression: she leaned backwards, frowned, wrinkled her nose and lifted her upper lip as she viewed the three objects in silence. Then, she looked ahead and labelled the objects in a nasal, tense, lower voice (e.g., *Can you find the* [*teebu*]*? Look at the* [*teebu*]! *Where is the* [*teebu*]*?*). At the end of the trial, with a disgusted facial expression, she leaned her body backwards away from the target object with a disgusted interjection (e.g., *Urgh! Look! There is the* [*teebu*]!), during which the target increased in size.

Reengagement Stimuli. After the five-minute break followed the referent selection part, in a seven-second reengagement video, the three novel objects were shown without the presence of the actress. Toddlers heard an audio recording of the same female actress saying

Welcome back! Let's play a game! Can you find what I am asking for? to help toddlers to reengage with the study (Twomey et al., 2017).

Retention Phases. In both retention phases (RT1, RT2), videos of six test trials consisted of three novel objects presented without the actress. The six test trials were divided into two blocks. One consisted of three label trials, and the other consisted of three no-label trials. The horizontal position of novel objects and trial order were counterbalanced across toddlers, and block order was reversed and counterbalanced in RT1 and RT2 across participants (see Figure 2.3). RT1 took place following the referent selection trials after a five-minute break. RT2 took place the following day within 36 hours of the toddlers completing the referent selection and RT1.

Label Trials. Label trials tested whether toddlers had retained the label-object associations. At the beginning of every trial, the three previously seen novel objects appeared accompanied by a chiming sound to attract toddlers' attention. Then, toddlers heard audio recordings of the same actress labelling the objects in neutral emotion (*Can you find the* [*label*]? *Look at the* [*label*]? *Where is the* [*label*]?).

No-label Trials. No-label trials tested whether toddlers had associated the objects with the emotions displayed during referent selection phase. At the beginning of every trial, three novel objects appeared, again accompanied by a chiming sound. Then, toddlers heard emotional cues but not labels (Neutral: *Look! Look at that! Look!* Positive: *Wow*! *Look*! *Wow*! *Look at that*! *Wow*! Negative: *Urgh*! *Look*! *Urgh*! *Look at that*! *Urgh*!).

Time Course of Stimulus Presentation. For the warm-up and referent selection phases, the detailed time course and label onsets of stimuli are presented in the Table 2.1. Retention trials lasted 8000 - 8200 ms. In label trials, first label onset was at 2000 ms, second label onset at 4000 ms, and third label onset 6000 ms after trial onset. For no-label trials, the onsets of emotional cues were at 2000 ms, 4000 ms and 6000 - 6200 ms (Neutral: *Look*! Positive: *Wow*! Negative: *Urgh*!). Afterwards, the three novel objects remained on the screen and the experimenter encouraged toddlers to point at the target.

Stimulus Ratings. In order to ensure that the effect of our stimuli was perceived as we intended, we asked sixty adult participants (46 females, M = 20.9 years old, SD = 7.21) to complete an online survey to assess the valence of the actress's emotional expressions and voice (neutral, positive and negative). Participants watched the 27 referent selection videos and listened to the 6 RT audio recordings, rating each stimulus as either neutral, positive or negative. We calculated average percentage agreement; agreement of 100% represents complete agreement and 33.33% indicates that participants disagreed maximally. For the referent selection videos ratings, agreement on the neutral videos was 95.56%, the positive videos 100%, and the negative videos 98.68%. For the retention no-label trials, agreement was 96.61% for neutral and 100% each for positive and negative trials. The retention label trials had a neutral rating of 92.6%.

Figure 2.2

An Example of Warm-up and Referent Selection Trials

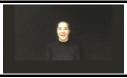
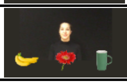
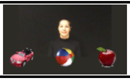
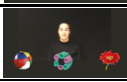
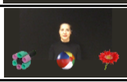
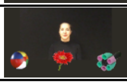
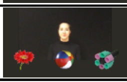
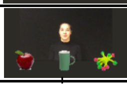
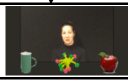
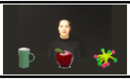
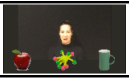
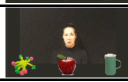
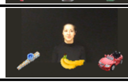
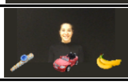
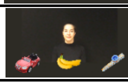
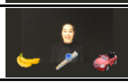
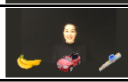
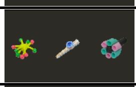
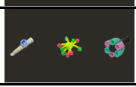
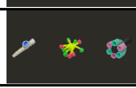
Trial	Stimuli	Emotion	Target
Engagement		n/a	n/a
Warm-up 1		neutral	flower
Warm-up 2		neutral	apple
RS block 1 trial 1		neutral	coodle
RS block 1 trial 2		neutral	flower
RS block 1 trial 3		neutral	ball
RS block 1 trial 4		neutral	coodle
RS block 1 trial 5		neutral	coodle
RS block 2 trial 1		neutral	apple
RS block 2 trial 2		negative	bosa
RS block 2 trial 3		neutral	cup
RS block 2 trial 4		negative	bosa
RS block 2 trial 5		negative	bosa
RS block 3 trial 1		neutral	banana
RS block 3 trial 2		positive	teebu
RS block 3 trial 3		neutral	car
RS block 3 trial 4		positive	teebu
RS block 3 trial 5		positive	teebu
Well done!		n/a	n/a
Five-minute break			

Figure 2.3

An Example of RT1 and RT2

RT1			
Trial Type	Stimuli	Emotion	Target
Re-engagement		n/a	n/a
No-label trial 1		neutral	coodle
No-label trial 2		negative	bosa
No-label trial 3		positive	teebu
Label trial 1		neutral	bosa
Label trial 2		neutral	coodle
Label trial 3		neutral	teebu

RT2			
Trial Type	Stimuli	Emotion	Target
Re-engagement		n/a	n/a
Label trial 1		neutral	bosa
Label trial 2		neutral	teebu
Label trial 3		neutral	coodle
No-label trial 1		neutral	coodle
No-label trial 2		negative	bosa
No-label trial 3		positive	teebu

2.2.3 Procedure

Before the experiment began, for the adults, the experimenter told participants that they would see some objects and hear a woman speaking and obtained the consent from them. Then, the adult participants were guided to a quiet, dimly lit room where participants sat 50-70 cm in front of a 21.5 in. 1920 × 1080 computer screen. For the caregivers and toddlers, the experimenter introduced the procedure and showed the caregiver the pictures of the objects used in the study to confirm that the toddlers knew the names of the six known objects but did not know the three novel objects. All caregivers reported that participants were familiar with the known objects and unfamiliar with the novel objects. Caregivers were informed that once the child had completed the referent selection and RT1 phases, they would be invited to return for RT2 the following day, within 36 hours of the first day's testing. Caregivers were also asked to complete the Oxford CDI (Hamilton et al., 2000). After the experimenter had obtained consent, caregivers and toddlers were guided to the room where participants sat on their caregiver's lap 50-70 cm in front of the computer screen. Caregivers were instructed to turn their head to one side or close their eyes and not to interact with their child. A Tobii X120 eye tracker (60Hz) beneath the screen recorded participants' gaze location, and a video camera above the screen recorded the participants throughout the study.

Before the task, both adults and toddlers were presented with a five-point calibration sequence. The calibration was run until at least four points were calibrated for each eye or up to three times if calibration of both eyes kept failing. All participants were then presented with the engagement trial followed by the two warm-up trials and the 15 referent selection trials. After the referent selection phase, participants took a five-minute break during which adults remained sitting in front of the computer screen, while toddlers played with toys (e.g., a ball, blocks) on a play mat. After the break, the RT1 phase started for adults immediately, while toddlers returned to their caregiver's lap, and the RT1 phase began. During the retention phase, the researcher encouraged all participants to point at the target objects by asking *Which one is it? Point at it! Which one is it?* after the audio stimuli stopped playing on each retention trial. The researcher was behind a curtain and therefore not visible to participants during this process. The next test trial was played when participants had made their choice or had not offered a response after being asked three times. Participants' points were recorded by the video camera above the screen for offline coding. RT2, on the next day, proceeded in an identical manner to RT1 except that the order of the blocks was reversed; that is, participants who encountered the label block first in RT1 encountered the no-label block first in RT2.

2.2.4 Data Cleaning and Model Selection

Raw looking time data was exported from Tobii Studio (version 3.2). Areas of interest (AOIs) were defined as rectangles of 536 pixels wide by 424 pixels tall centred on each object's position on the screen. A further face AOI was 471 pixels wide by 419 pixels tall and centred on the actress's face for the RS phase. Only gaze points that fell into AOIs entered analyses. Data cleaning and analysis were carried out in the R package *eyetrackingR* (Dink & Ferguson, 2015). Trials in which the eye tracker lost the eyes for more than 50% of the trial duration were excluded from analyses. Thus, for adults' data, 223 out of 243 trials were included for the analyses of the referent selection phase (91.77%); 143 out of 162 for RT1 (88.82%); and 141 out of 162 for RT2 (87.04%). For toddlers' data, 239 out of 297 trials were included for the analyses of the referent selection phase (80.47%); 129 out of 180 trials for RT1 (71.67%), and 117 out of 174 trials for RT2 (67.24%). One toddler did not return for RT2; analyses of RT2 therefore contain six fewer trials than RT1. Participants' pointing was coded offline by the experimenter; a point was coded as the first pointing location (left, middle, right) after the third label or cue onset in the retention trials. Points from 27 adults and 32 toddlers who pointed in more than two trials in each retention phase entered analyses (adults: 324; toddlers: 319 trials). A second coder, naïve to the experimental hypotheses, additionally coded 50% of the recordings. Intercoder reliability (Cohen's Kappa) was high for both adults (.87) and toddlers (.87).

Data were analysed in *RStudio* (version 1.0.153; RStudioTeam, 2015). We used the *lmer* function from the *lme4* package to fit linear mixed-effect models (LMEMs) in R (Bates et al., 2015). The effect size reported for LMEMs was R^2_m and R^2_c, which were the effect sizes explained by fixed effects in the model and by the entire model, respectively (Nakagawa & Schielzeth, 2013). Random effects structure in LMEMs was determined by Chi-square tests, which were conducted by the *anova* function from the *states* package in R (Chambers & Hastie, 1992). To take into account individual differences in emotion perception (Lee et al., 2012), we first fitted a model with by-item, by-participant, by-affect random intercepts and by-participant random slopes for affect. To determine the structure of final random effects, we removed random slopes and intercepts in a hierarchical manner. If dropping a random effect improved model fit, this effect was eliminated from the model; if dropping a random effect did not improve model fit, only the random intercepts for items and participants entered the final model.

We also report Bayes factors (BF_{01}) for focal analyses to provide evidence for the degree to which the null hypothesis (H_0) was supported when frequentist analyses were non-significant (Lakens et al., 2020). For BF_{01} greater than 1, the non-significant frequentist analyses were considered supportive of null hypothesis; for BF_{01} smaller than 1 but greater than 0.1 (i.e., $1 < BF_{10} < 10$), the analyses are suggested to be underpowered and inconclusive for supporting the null or alternative hypotheses; for BF_{01} smaller than 0.1 (i.e., $BF_{10} > 10$), the analyses were considered as a strong supportive evidence of the alternative hypotheses (see Wiley & Jarosz, 2014, for detailed description). The prior of the Bayesian statistics in the analyses was set as default (null hypothesis), assuming the experimental variables had no effect on the dependent variables. However, when the value of BF_{01} is smaller than 0.1, it indicates strong evidence that the experimental variables had an effect on the dependent variables. The *BayesFactor* package was used to calculate Bayes factors (Morey et al., 2015). Cohen's d was also reported for the effect size of *t*-tests.

2.3 Results

We first present results from the referent selection and retention phases in adults, followed by results from toddlers. In order to uncover how labelling affect influenced participants' attention distribution during learning and the developmental change of emotional information processing, we report, for the referent selection phase, participants' proportion face looking (looking to face AOI / looking to all four AOIs) and target looking (looking to target AOI / looking to three object AOIs) following the first label onset until the trial end and a comparison between adults' and toddlers' looking. To examine the word learning outcome and retention of emotion-object associations, for the retention phases, we analysed participants' proportion target looking (looking to target AOI / looking to all three AOIs) and pointing data to test whether participants retained label-object and emotion-object associations differently based on the labelling affect associated with objects, and whether retention differed across the two retention phases.

2.3.1 Adults

2.3.1.1 Referent selection

Twenty-seven adults' eye tracking data entered the analyses of the referent selection phase. The dependent variables were adults' proportion face looking and proportion target looking following the first label onset until the trial end.

Proportion Face Looking. Adults' proportion face looking after label onset differed according to the labelling affects in referent selection trials, revealed by a LMEM with a fixed effect of affect (neutral, positive, negative) and by-item and by-participant random intercepts ($\chi^2(2) = 9.33$, $p = .009$, $R^2_m = .02$, $R^2_c = .53$). The proportion face looking in the negative referent selection trials was higher than that in the neutral referent selection trials (neutral: $M = 0.18$, $SD = 0.17$; negative: $M = 0.25$, $SD = 0.21$; $\beta = 0.07$, $SE = 0.02$, $z = 2.99$, $p = .008$). The proportion face looking in the positive referent selection trials ($M = 0.20$, $SD =$

0.22) was similar to that in the neutral and negative referent selection trials (neutral: β = 0.02, *SE* = 0.02, *z* = 0.98, *p* = .59; negative: β = -0.05, *SE* = 0.02, *z* = -2.04, *p* = .10).

Proportion Target Looking Among Objects. Adults' proportion target looking was similar across affect, revealed by a LMEM with a fixed effect of affect and by-item and by-participant random intercepts ($\chi^2(2) = 0.80$, $p = .67$, $R^2_m = .004$, $R^2_c = .24$, $BF_{01} = 17.80$; neutral: *M* = 0.95, *SD* = 0.11; positive: *M* = 0.96, *SD* = 0.08; negative: *M* = 0.96, *SD* = 0.12). Overall, therefore, adults looked to the negative face more than to the neutral face but attended to the three targets similarly regardless of affect.

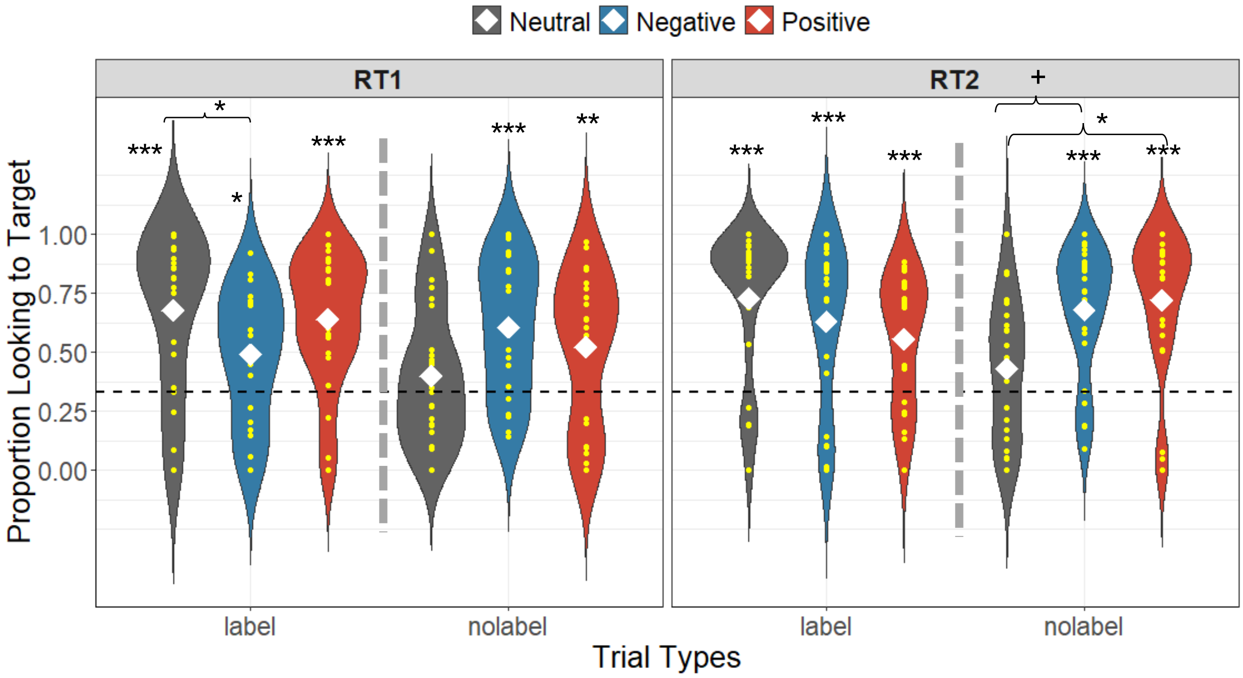
2.3.1.2 Retention

At test, on the label trials participants heard all targets labelled in neutral affect, and on no-label trials toddlers heard the three emotional cue types. After data cleaning, eye tracking data from 27 adults entered the analyses of both RTs. To analyse the retention of label-object and emotion-object associations, we compared proportion target looking in a 6500 ms time window after the first label onset in both label and no-label trials against chance (.33) with a two-tailed, one-sample *t*-test (Figure 2.4). The time window was chosen to ensure participants' fixations after hearing all the labels or cues were fully collected (Okumura et al., 2017; Twomey et al., 2017). Additionally, we employed LMEMs to explore the impact of affect associated with novel objects (emotionality of objects) on visual attention in the label and no-label trials. Pointing from 27 adults entered the analyses in both RT phases. The probability of most pointing to one object, either target or distractors in each retention trial, were compared with random pointing (.33) using the Chi-Square Goodness-of-Fit Test

(Howell, 2013). We coded points as *target* and *positive/negative/neutral distractor* (Table 2.2).

Figure 2.4

Proportion Target Looking Time of Adults in the Retention Phases



Note. White diamonds indicate the means of proportion target looking. Dashed line represents chance (0.33). *** $p < .001$; ** $p < .01$; *$p < .05$; $^{+}$ $p > .05$ but $BF_{01} < 0.1$.

Table 2.2

Adults' Pointing to Target and Distractors in the Retention Phases

Affect	RT1					RT2				
	Target	Distractor (*n*)			$\chi^2(2)$	Target	Distractor (n)			$\chi^2(2)$
	n (*N*)	Neutral	Positive	Negative		*n* (*N*)	Neutral	Positive	Negative	
					Label trials					
Neutral	21 (27)	-	5	1	24.89^{***}	21 (27)	-	4	2	24.22^{***}
Positive	20 (27)	2	-	5	20.67^{***}	19 (27)	6	-	2	17.56^{***}
Negative	19 (27)	6	2	-	17.56^{***}	23 (27)	3	1	-	32.89^{***}
					No-label trials					
Neutral	17 (27)	-	4	6	10.89^{**}	18 (27)	-	3	6	14.00^{***}
Positive	22 (26)	4	-	0	31.69^{***}	22 (27)	2	-	3	28.22^{***}
Negative	25 (27)	1	1	-	42.67^{***}	25 (27)	0	2	-	42.89^{***}

Note. *N* is the total number of toddlers who pointed in a particular RT trial. *n* is the number of toddlers who pointed to a particular object. *** $p < .001$; ** $p < .01$; $^{*}p < .05$.

Label Trials in RT1. Adults looked to all targets at levels greater than expected by chance (neutral: $M = 0.64$, $SD = 0.31$, $t\ (22) = 4.88$, $p < .001$, $d = 1.00$; positive: $M = 0.59$, $SD = 0.24$, $t\ (22) = 5.16$, $p < .001$, $d = 1.06$; negative: $M = 0.46$, $SD = 0.24$, $t\ (23) = 2.55$, $p = .02$, $d = 0.51$). Meanwhile, adults' proportion target looking was different between the different affect, revealed by a LMEM with a fixed effect of affect (neutral, positive, negative) and random intercepts for items and participants ($\chi^2(2) = 7.22$, $p = .027$, $R^2{}_m = .00$, $R^2{}_c = .15$). Planned post-hoc Tukey's HSD tests indicated that adults looked longer to the neutral than to negative target ($\beta = 0.19$, $SE = 0.07$, $z = 2.59$, $p = .03$), but not to the positive target ($\beta = 0.05$, $SE = 0.07$, $z = 0.68$, $p = .78$, $BF_{01} = 2.94$). Looking time between positive and negative did not differ ($\beta = 0.14$, $SE = 0.07$, $z = 1.91$, $p = .14$, $BF_{01} = 0.79$).

Pointing. 21, 20 and 19 out of 27 adult pointed to neutral, positive, and negative targets respectively, above chance.

Label Trials in RT2. On the second day, adults looked to the three targets at levels greater than expected by chance (neutral: $M = 0.72$, $SD = 0.31$, $t\ (19) = 5.74$, $p < .001$, $d = 1.27$; positive: $M = 0.55$, $SD = 0.27$, $t\ (23) = 4.08$, $p < .001$, $d = 0.82$; negative: $M = 0.63$, $SD = 0.33$, $t\ (22) = 4.28$, $p < .001$, $d = 0.88$). No differences were found in adults' proportion target looking between the different affect, revealed by a LMEM with a fixed effect of affect and random intercepts for items and participants, $\chi^2(2) = 4.05$, $p = .13$, $R^2_m = .00$, $R^2_c = .06$, $BF_{01} = 230.48$).

Pointing. 21, 19 and 23 out of 27 adult pointed to neutral, positive, and negative targets respectively, above chance.

No-label Trials in RT1. After hearing neutral cues, adults did not looked at the neutral targets at above-chance levels ($M = 0.40$, $SD = 0.29$, $t\ (24) = 1.20$, $p = .24$, $d = 0.23$, $BF_{01} = 0.40$), but after hearing positive and negative cues, they looked to corresponding targets above chance (positive: $M = 0.52$, $SD = 0.32$, $t\ (21) = 2.80$, $p = .01$, $d = 0.59$; negative: $M = 0.61$, $SD = 0.28$, $t\ (24) = 4.87$, $p < .001$, $d = 0.96$). No differences were found in adults' proportion target looking between the different affects, revealed by a LMEM with a fixed effect of affect and random intercepts for items and participants ($\chi^2(2) = 2.87$, $p = .24$, $R^2_m = .00$, $R^2_c = .55$, $BF_{01} = 0.81$).

Pointing. 17 and 25 out of 27 adult pointed to neutral and negative targets above chance; 22 out of 26 pointed to positive targets above chance.

No-label Trials in RT2. On the second day, like on the first day, after hearing neutral cues adults did not look at the neutral targets at above-chance levels ($M = 0.43$, $SD = 0.29$, t

(23) = 1.69, p = .10, d = 0.33, BF_{01} = 1.35). Also like the first day, after hearing positive and negative cues they looked to corresponding targets above chance (positive: M = 0.72, SD = 0.30, t (24) = 6.58, p < .001, d = 1.31; negative: M = 0.67, SD = 0.27, t (24) = 6.51, p < .001, d = 1.29). Adults' proportion target looking was different between the different emotional affects, revealed by a LMEM with a fixed effect of affect and random intercepts for items and participants ($\chi^2(2)$ = 7.83, p = .02, R^2_m = .00, R^2_c = .57). Planned post-hoc Turkey's HSD test indicated that adults' looking to positively cued target was greater than to neutrally cued targets (β = 0.27, SE = 0.11, z = 2.61, p = .02), but not to negatively cued targets (β = 0.05, SE = 0.10, z = 0.44, p = .90, BF_{01} = 3.15). Their looking to the negatively cued targets was longer than to the neutrally cued targets suggested by BF_{01} (β = 0.23, SE = 0.11, z = 2.18, p = .07; BF_{01} = 0.08).

Pointing. 18, 22 and 25 out of 27 adult pointed to neutral, positive and negative targets respectively, above chance.

Overall, adults looked and pointed to targets for all the label-object associations and looked to neutral target longer than negative target longer on RT1. They looked and pointed to the positive and negative targets after hearing the corresponding cues, and although their looking to the neutral target after hearing the neutral cues was at chance, most adults pointed to the neutral target.

2.3.2 Toddlers

2.3.2.1 Referent selection

Thirty-two out of 38 toddlers' eye tracking data entered the analyses of the referent selection phase after data cleaning. Data from six participants who looked for less than 50% of every trial were removed. The dependent variables were toddlers' proportion face looking and proportion target looking following the first label onset until the trial end.

Proportion Face Looking. We first submitted proportion face looking and to a LMEM with a fixed effect of affect. The best-fitting random effects structure included by-item, by-participant, by-affect random intercepts ($\chi^2(1) = 28.65$, $p < .001$). Toddlers' proportion face looking after label onset differed according to labelling affect in referent selection trials ($\chi^2(2) = 59.11$, $p < .001$, $R^2_m = .20$, $R^2_c = .59$). Compared with proportion face looking in the neutral referent selection trials ($M = 0.44$, $SD = 0.18$), that in the negative and positive referent selection trials was higher (negative: $M = 0.66$, $SD = 0.18$; $\beta = 0.21$, $SE = 0.03$, $z = 7.68$, $p < .001$; positive: $M = 0.56$, $SD = 0.16$; $\beta = 0.11$, $SE = 0.03$, $z = 4.05$, $p < .001$). The proportion face looking in the negative referent selection trials was greater than that of positive referent selection trials ($\beta = 0.10$, $SE = 0.03$, $z = 3.52$, $p = .001$).

Proportion Target Looking among Objects. We then submitted proportion target looking to a LMEM with a fixed effect of affect (neutral, positive, negative). The best-fitting random effects structure included by-item, by-participant random intercepts. Toddlers showed similar patterns of looking to targets labelled in the different affects ($\chi^2(2) = 3.44$, $p =$

0.18, $R^2{}_m$ = .02, $R^2{}_c$ = .15, BF_{01} = 1.54, neutral: *M* = 0.78, *SD* = 0.21; positive: *M* = 0.82, *SD* = 0.15; negative: *M* = 0.85, *SD* = 0.18).

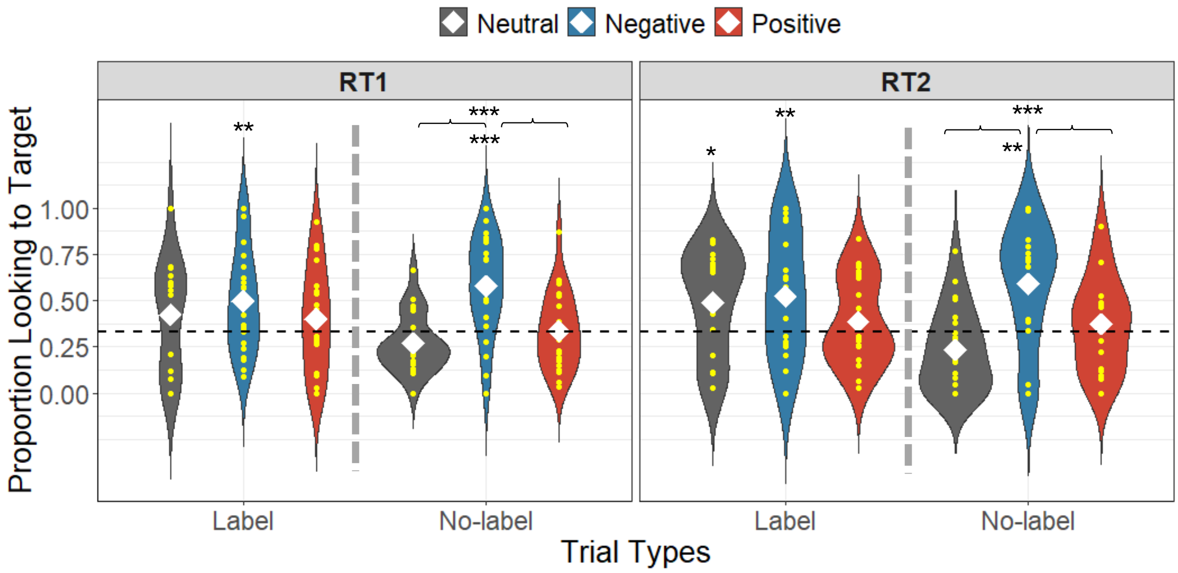
Overall, therefore, during the referent selection phase, toddlers looked to the neutral face the least and to the negative face the most; meanwhile, they attended to the target objects similarly between labelling affect.

2.3.2.2 Retention

After data cleaning, data from 29 toddlers entered the looking time analyses of RT1 and data from 28 toddlers for RT2. Toddlers' proportion target looking in the label and no-label trials is shown in Figure 2.5. Pointing from 30 toddlers entered the analyses in both retention phases. Toddlers' probability of preferential pointing to one object, either target or distractors in each retention trial, is shown in Table 2.3.

Figure 2.5

Proportion Target Looking Time of Toddlers in the Retention Phases



Note. White diamonds indicate the means of proportion target looking. Dashed line represents chance (0.33). *** *p* < .001; ** *p* < .01; **p* < .05.

Table 2.3

Toddlers' Pointing to Target and Distractor in the Retention Phases

Affect	RT1					RT2				
	Target	Distractor (*n*)			$\chi^2(2)$	Target	Distractor (n)			$\chi^2(2)$
	n (*N*)	Neutral	Positive	Negative		*n* (*N*)	Neutral	Positive	Negative	
Label trials										
Neutral	23 (29)	-	5	1	28.41***	20 (28)	-	3	5	18.50***
Positive	12 (27)	10	-	5	2.89	11 (29)	10	-	8	0.48
Negative	20 (28)	6	2	-	19.14***	21 (28)	2	5	-	22.36***
No-label trials										
Neutral	4 (22)	-	5	13	6.64*	4 (26)	-	5	17	12.08***
Positive	8 (22)	3	-	11	4.45	6 (27)	6	-	15	6.00*
Negative	21 (25)	3	1	-	29.12***	23 (28)	4	1	-	30.50***

Note. N is the total number of toddlers who pointed in a particular RT trial. *n* is the number of toddlers who pointed to a particular object. *** $p < .001$; ** $p < .01$; * $p < .05$.

Label Trials in RT1. Toddlers did not look at neutral and positive targets at levels greater than expected by chance (neutral: M = 0.42, SD = 0.30, t (15) = 1.25, p =.23, d = 0.30, BF_{01} = 2.04; positive: M = 0.40, SD = 0.28, t (18) = 1.07, p = .30, d = 0.23, BF_{01} = 2.56). However, they looked at negative targets at above-chance levels (M = 0.50, SD = 0.28, t (22) = 2.91, p = .008, d = 0.59). No differences in proportion target looking was found between the different affect, revealed by a LMEM with a fixed effect of affect and random intercepts for items and participants ($\chi^2(2)$ = 1.58, p = .45, R^2_m = .02, R^2_c = .13, BF_{01} = 348.59).

Pointing. 23 out of 29 and 20 out of 28 toddlers pointed to neutral and negative targets, above chance respectively; but only 12 out of 27 toddlers pointed to positive targets, at chance.

Label Trials in RT2. On the second day, toddlers looked to neutral and negative targets at levels greater than expected by chance (neutral: $M = 0.49$, $SD = 0.28$, $t\ (18) = 2.54$, $p = .02$, $d = 0.57$; negative: $M = 0.52$, $SD = 0.33$, $t\ (20) = 2.67$, $p = .01$, $d = 0.57$), whereas they did not look to positive targets at above-chance levels ($M = 0.39$, $SD = 0.24$, $t\ (19) = 1.05$, $p = .30$, $d = 0.22$, $BF_{01} = 2.63$). Like on the first day, no differences in proportion target looking were found between the different emotional affects, revealed by a LMEM with a fixed effect of affect and by-items and by-participants random intercepts ($\chi^2(2) = 3.21$, $p = .20$, $R^2_m = .05$, $R^2_c = .18$, $BF_{01} = 384.41$).

***Pointing*.** Twenty out of 28 and 21 out of 28 toddlers pointed to neutral and negative targets, above chance respectively; but only 11 out of 29 toddlers pointed to positive targets, at chance.

Overall, therefore, toddlers looked and pointed to negative target on both days and to neutral target on the second day. Although toddlers did not look to the neutral target above chance on the first day, most of them still pointed to the neutral target. These results indicate that they retained neutral and negative, but not positive label-object associations.

No-label Trials in RT1. After hearing neutral and positive cues, toddlers did not look at the corresponding targets at above-chance levels (neutral: $M = 0.27$, $SD = 0.16$, $t\ (21) = -1.76$, $p = 0.09$, $d = -0.40$, $BF_{01} = 1.19$; positive: $M = 0.34$, $SD = 0.20$, $t\ (22) = 0.16$, $p = .87$, $d = 0.02$, $BF_{01} = 4.52$), but after hearing negative cues they did look to negative targets at above-chance levels ($M = 0.58$, $SD = 0.26$, $t\ (25) = 4.90$, $p < .001$, $d = 0.95$). Toddlers' proportion target looking was differed between different affect, revealed by a LMEM with a fixed effect of affect and by-items and by-participants random intercepts ($\chi^2(2) = 29.25$, $p < .001$, $R^2_m = .29$, $R^2_c = .29$). Planned post-hoc Tukey's HSD tests indicated that toddlers looked to the negatively cued targets more than to neutrally and positively cued targets (neutral: $\beta = 0.31$, $SE = 0.06$, $z = 5.07$, $p < .001$; positive: $\beta = 0.24$, $SE = 0.06$, $z = 4.02$, $p < .001$); their looking to the positively and neutrally cued targets was not different ($\beta = 0.07$, $SE = 0.06$, $z = 1.06$, $p = .54$, $BF_{01} = 1.88$).

***Pointing*.** Only 4 out of 22 toddlers pointed to neutral targets but 13 pointed to negative distractors, which is above chance; only 8 out of 22 pointed to positive targets, at chance; 21 out of 25 toddlers pointed to negative targets, above chance.

No-label Trials in RT2. As on the first day, after hearing neutral and positive cues, toddlers did not look at the corresponding targets at above-chance levels (neutral: $M = 0.23$, $SD = 0.22$, t (21) = - 0.20, $p = 0.06$, $d = 0.44$, $BF_{01} = 0.84$; positive: $M = 0.37$, $SD = 0.25$, t (16) = 0.72, $p = .48$, $d = 0.16$, $BF_{01} = 3.30$) but again, after hearing the negative cue, they looked to the negative target above chance ($M = 0.59$, $SD = 0.33$, t (17) = 3.36, $p = .004$, $d = 0.78$). Toddlers' proportion target looking differed by affect, revealed by a LMEM ($\chi^2(1) = 5.27$, $p = .02$) with fixed effect of affect and by-items, by-participants and by-affect random intercepts ($\chi^2(2) = 18.34$, $p < .001$, $R^2_m = .25$, $R^2_c = .25$). Planned post-hoc Turkey's HSD test indicated that toddlers' looking to negatively cued targets was greater than to neutrally and positively cued targets (neutral: $\beta = 0.36$, $SE = 0.08$, $z = 4.27$, $p < .001$; positive: $\beta = 0.22$, $SE = 0.09$, $z = 2.44$, $p = .04$); their looking to the positively and neutrally cued targets was not different ($\beta = 0.14$, $SE = 0.08$, $z = 1.65$, $p = .22$, $BF_{01} = 0.88$).

Pointing. Only 4 out of 26 toddlers pointed to neutral targets but 17 pointed to the negative distractor, which is above chance; only 6 out of 27 pointed to positive targets but 15 pointed to the negative distractor, above chance; and 23 out of 28 toddlers pointed to negative targets, above chance.

Overall, toddlers looked and pointed to the negative target after hearing negative cues in both retention phases. They did not look to the neutral target but pointed to the negative distractor after hearing neutral cues. However, they looked and pointed to the three objects randomly after hearing the positive cues on the first day despite more than half of them pointing to the negative distractor on the second day, indicating that toddlers tended to attend more to negative objects in the no-label trials.

2.3.3 Comparison of Visual Attention between Toddlers and Adults

To explore the potential developmental difference of visual attention between toddlers and adults when learning novel label-object associations in terms of different labelling affect, we compare toddlers' and adults' proportion face and target looking in the referent selection phase.

2.3.3.1 Referent Selection

Proportion Face Looking. To examine the difference of face looking between adults and toddlers in terms of labelling affect during learning, we submitted proportion face looking to a LMEM with a fixed effect of an interaction of affect and age group (toddlers, adults) and by-item, by-participant and by-affect random intercepts ($\chi^2(1) = 30.16$, $p < .001$), revealing a significant effect of the interaction ($\chi^2(5) = 109.97$, $p < .001$, $R^2_m = .29$, $R^2_c = .84$).

Planned Turkey's HSD test indicated that toddlers looked to the actress' face longer than adults did in all the referent selection trials (neutral: $\beta = 0.26$, $SE = 0.04$, $z = 6.47$, $p < .001$; positive: $\beta = 0.36$, $SE = 0.04$, $z = 0.14$, $p < .001$; negative: $\beta = 0.41$, $SE = 0.04$, $z = 10.05$, $p < .001$).

Proportion Target Looking. Regarding the difference of target object looking between adults and toddlers in terms of labelling affect during learning, we submitted proportion target looking to a LMEM with a fixed effect of an interaction of affect and age group and by-item, by-participants random intercepts, revealing a significant effect of the interaction ($\chi^2(5) = 70.14$, $p < .001$, $R^2_m = .20$, $R^2_c = .34$). Planned Turkey's HSD test indicated that adults looked to the targets longer than toddlers did in all the referent selection trials (neutral: $\beta = 0.17$, $SE = 0.03$, $z = 1.27$, $p < .001$; positive: $\beta = 0.14$, $SE = 0.03$, $z = 5.24$, $p < .001$; negative: $\beta = 0.12$, $SE = 0.03$, $z = 4.65$, $p < .001$).

Overall, compared with adults, during the learning phase, toddlers looked more to the actress's face but less to the targets.

2.4 Discussion

Chapter 2 examined the effect of perceived emotions on adults' and toddlers' encoding and retention of novel label-object and emotion-object associations, both five minutes after learning and one day later. Adults retained all the label-object and emotion-object associations and associated all the affective cues with the corresponding objects, indicated by their looking and pointing. For toddlers, our hypothesis was that toddlers would retain positively and negatively trained associations better than the neutral ones because infants are found allocating more attention to objects associated with negative affect (Hoehl, 2014) and better generalizinng positive vocalizations compared with neutral affect (Sign et al., 2004). However, in contrast to expectations, toddlers identified neutrally and negatively trained label-object association but failed to identify the positive one. When hearing the corresponding affective cues, toddlers recognised the negatively trained objects but not the neutrally or positively trained objects. Notably, a majority of toddlers pointed at the negative distractor after hearing neutral (both days) and positive (RT2) cues. Furthermore, regarding the potential differences of visual attention between adults and toddlers in terms of emotional information processing during learning, we found that adults focused on target objects, but toddlers attended to the actress's face. Together, these results suggest that adults' and toddlers' attentional processing is different during the learning process and recognition of newly learned label-object and emotion-object associations under the impact of perceived emotions, which are discussed below.

During the referent selection phase in which participants learned the associations, adults demonstrated a goal-oriented looking behaviour of looking to the targets while toddlers showed a preference to the actress' face. This finding is in line with the evidence that young children are attracted to human faces generally (e.g., Sanefuji et al., 2014) and that toddlers rely on others' expressions to acquire reliable information (Clément & Dukes, 2017), especially when encountering novel objects or ambiguous situation (e.g., Moses et al., 2001; Sorce et al., 1985), but shows that adults were less influenced by others' affective expressions when they were irrelevant to the learning task. Additionally, both adults and toddlers looked more at the face in the negative than in the positive and neutral condition, in line with research suggesting that affectively negative faces capture more attention from toddlers and adults (e.g., Hoehl, 2014; Kauschke et al., 2019; Leppänen et al., 2007). However, this increased face looking did not interfere with learning the referents of labels, as revealed by the similar amount of looking to target objects in the referent selection phase. Overall, during the learning phase, compared with adults, toddlers are still attracted by others' face when processing multiple sensory input; but both adults and toddlers are attracted by the emotionally negative expressions. Although the labelling affect did not affect the looking time of novel objects during referent selection, the learning outcome might be affected by the emotions associated with the objects, especially for the toddlers.

During the testing phases, to demonstrate retention of label-object and emotion-object associations, individuals need to integrate auditory (the label, affective cue), and perceptual (the referent) information, and then adjust attention to the target among a set of distractors (Samuelson & Smith, 2000). For toddlers, this process can be facilitated by their familiarity with the referent (Kucker & Samuelson, 2012) but interrupted by the presence of salient distractors (Horst et al., 2010; Pomper & Saffran, 2018). Specifically, toddlers' attention might be affected by the features of targets, distractors, and labels or affective cues they heard when recognising the target associations. Thus, the testing task might be challenging to toddlers. In the label trials, toddlers heard all labels presented in neutral affect. Thus, for the positively and negatively trained associations, toddlers were required to generalise novel labels across emotional affect (Singh et al., 2004). In contrast, on neutral label trials, no generalisation was necessary, which lowered the task demands for neutrally trained label-object associations and could explain why the majority of toddlers pointed to the neutral targets but not to positive targets. In positive retention trials, toddlers were faced with two difficulties: the need to generalise the label to neutral affect, and the presence of the salient negative distractor. In negative trials, despite having to generalize to neutral affect in retention, the negativity bias might have helped target identification (e.g., Hoehl et al., 2008; Vaish et al., 2008). Therefore, the requirement of generalisation and the negativity bias might be the reasons why toddlers did not recognise the positive target but succeeded with neutral and negative targets.

Moreover, toddlers demonstrated a negativity bias when hearing the affective cues. Apart from identifying the negative object after hearing negative cues, they even pointed to negative objects after hearing neutral and positive cues, suggesting that the negative object captured their attention generally regardless of what types of affective cues they heard. But for adults, during the retention task, they managed to integrate the labels or affective cues they heard and the novel objects they saw, and then adjust attention to as well as identify the target among a set of distractors. Specifically, although the negative visual stimuli still capture adults' attention (Yuan et al., 2019), the negativity bias did not override target identification, indicating that adults demonstrated a developed top-down attentional control in the current retention task.

Notably, in addition to looking time, we also measured pointing to reflect an unambiguous target identification. Similar to the situation found in toddlers that they did not look but point to target, adults did not look to the neutral target in the no-label trials when hearing neutral cues but pointed to it, suggesting that the proportion target looking might not reflect the outcome of target identification. Indeed, word learning studies employing referent selection and retention paradigm have already found that the methods used to measure retention affect the conclusion that whether toddlers retained the newly learned label-object associations or not. In a testing task where placed three-dimensional newly learned objects on a tray and required toddlers to select the target, the 24-month-olds manged to pick the correct objects (Hilton & Westermann, 2017). But the same age group failed to show above chance proportion target looking, suggested as an index of retention, in a testing task where displayed the new-learned objects on the computer screen and only measured toddlers' looking time (Hilton et al., 2019). Thus, the pointing collected in the current task helps to disambiguate the measurement of looking time in terms of target recognition.

On the other hand, taking measurements of proportion target looking and pointing as indices of retention into account, toddlers failed to show retention of positive label-object associations because they neither looked nor pointed to the targets. These results may reflect that the toddlers did not retain the positive label-object association at all. However, according to the mutual exclusivity assumption (Markman, 1994), the toddlers should also have recognised the positive label-object association when the neutral and negative label-object associations were retrieved successfully. Therefore, regarding toddlers, we take two insights from above considerations: first, proportion target looking might not be an accurate measure of retention in the presence of salient competitors – for example, although toddlers did not look systematically to the neutral target in the label trials on the first day, they pointed to the target, indicating they had learned it. Second, target looking is a function of target and distractor salience, corresponding with top-down and bottom-up processing. Target salience was reduced in positive label trials because of the need for generalisation of labelling affect, which was not the case for neutral targets. Moreover, the impact of salient distractors could also account for toddlers' looking and pointing behaviours in the no-label trials: the presence of the negative objects may have interfered with their recognition of the association between affective cues and objects. Thus, there is a possibility that the 30-month-olds' retention of positively trained label-object and emotion-object associations could be masked by the presence of salient negative competitor.

All in all, Chapter 2 revealed that adults' retention of newly learned associations was not affected by the perceived emotions during referent selection phase and demonstrated a more mature top-down control of visual attention than toddlers did in terms of target identification during retention phase: they identified the cue-related target correctly and sustained their looking and pointed to the targets. However, toddlers' identification of target associations might be influenced by the task demand and the presence of salient negative distractor, especially for the positively trained associations. Thus, we conducted the second experiment described in Chapter 3 to test the assumption that distractor salience masked retention by reducing the number of distractor items to one.

Chapter 3: The Effect of Distractor Salience on Visual Attention and the Retrieval of Label-Object Associations

3.1 Introduction

Based on the findings described in Chapter 2, Chapter 3 aimed at replicating the retention results of neutral and negative target label-object associations while examining whether, in Chapter 2, toddlers' failure to identify positive targets indicated a true lack of retention of this mapping or whether this finding was due to the influence of the salient negative distractor. Moreover, the general negativity bias found in the no-label trials of Chapter 2 motivated us to further examine the implicit impact of newly learned negative emotion-object association on toddlers' visual attention.

In Chapter 2 we found that toddlers demonstrated a negativity bias regardless of which affective cues they heard, suggesting that the objects with negative emotionality might place an implicit effect on attention distribution when no label was specified. Research with adults has demonstrated that, compared with their neutral or positive counterparts, negative stimuli occupy more attentional resources during counting and discrimination tasks, reflected by slower reaction time, more active frontal-parietal areas etc. (e.g., Eastwood et al., 2003; Shafer et al., 2012). Although Flom and Johnson (2011) reported that 12-month-olds preferentially looked to positively than negatively associated novel objects after being habituated the objects paired with others' positive and negative expressions, 30-month-olds showed a negativity bias during object processing. This could be taken as evidence for a developmental change, after which 30-month-olds behave more like adults. Therefore, toddlers’ attention could be grabbed by the negative objects in the current task.

Second, although the 30-month-old toddlers failed to show retention of positive label-object association via both looking and pointing, toddlers of the same age have shown retention of newly learned object-associations in previous research employing a similar paradigm (Horst et al., 2010). Horst et al. (2010) examined whether the number of competitors during the referent selection phase affected toddlers’ learning of label-object associations. The 30-month-olds learned four novel label-object associations presented in pairings with either two, three or four competitors in the referent selection phase. In a retention test after a five-minute delay, only the toddlers who had encountered two competitors in the referent selection phase demonstrated retention of the label-object associations. In our current design, the 30-month-olds also encountered only two competitors during the referent selection phase, and furthermore, based on the mutual exclusivity assumption (Markman, 1994), although the generalisation from positively spoken labels to neutrally spoken labels is required in the retention part, the toddlers should also have recognised the positive label-object association when the neutral and negative associations were recognised.

Thus, in the current chapter, to address the surprising result that toddlers did not retain the positive label-object associations, we examined the possibility that the presence of a salient negative distractor masked target looking as an indicator of retention of the positive association. To remove the impact of negative distractor items on target looking and to decrease the task demands of processing three novel objects on the screen, here the retention trials contained only one distractor. Thus, in the test trials which presented the neutrally and positively conditioned novel objects, the impact of a negativity bias on visual attention is eliminated. Specifically, if toddlers' target looking was affected by the negative distractor in the previous experiment, in Experiment 2 they should recognise the target label-object associations by sustaining their looking to above chance level after the negative distractor was removed. Additionally, to further explore the effect of a negativity bias on visual attention, we only used neutral affective cues in the no-label trials in the current experiment. In this case, by presenting only two novel objects in the no-label trials, the effect of a negativity bias on visual attention will be revealed by showing toddlers' looking to negative objects when paired with neutral or positive object.

In sum, the experiment described in this chapter was designed to investigate, first, whether toddlers show preferential looking to the positive label-object association when paired with only one distractor; and second, the impact of negative emotion-object associations on visual attention. we hypothesised that toddlers would show above-chance target looking for all targets, indicating retention of label-object mappings irrespective of affect. We also hypothesised that the negative object might grab toddlers' visual attention in the no-label trials when toddlers heard only neutral cues.

3.2 Method

3.2.1 Participants

Forty 29- to 31-month-old typically developing British monolingual English-learning toddlers (16 girls, *M* = 926.95 days, *SD* = 23.00 days; range = 883 – 963 days old) participated in the study. An additional 13 toddlers were excluded from analyses for fussiness, as defined by failure to remain on the caregiver's lap (7); caregiver intervention (3); eye tracker error (2); and experimenter error (1). Toddlers' mean productive vocabulary was 353.27 words (*SD* = 57.89, range = 164 – 412). Caregivers gave consent to participate and received travel reimbursement. Toddlers were given a story book for taking part.

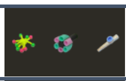
3.2.2 Procedure and design

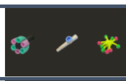
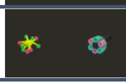
The procedure of Chapter 3 was identical to that in Chapter 2: a referent selection phase followed by a five-minute break, then retention test 1 (RT1), with participants completing retention test 2 (RT2) on the following day. However, we adapted the design in the following ways: first, referent selection trials in which the novel objects were targets were 20 s long, with the four label onsets occurring at 8000 ms, 10300 ms, 13000 ms, and 18000 ms after trial onset. Second, presentation order of neutral, positive, and negative blocks within the referent selection phase was counterbalanced.

In the retention phases (Figure 3.1), in contrast to Chapter 2, only two out of the three novel objects were presented in each retention trial to delineate the impact of labelling affect and distractor items on looking times and pointing. Each retention phase consisted of three blocks: two blocks of three label trials were presented in the first and the third blocks, while one block of three no-label trials was presented in the second block. Three object pairs were presented in each block: *neutral-positive*, *neutral-negative*, and *negative-positive*. In line with the label trials in Chapter 2, the target was labelled three times in neutral affect on each label trial (e.g., *Can you find the coodle*? *Look at the coodle*. *Where is the coodle*?). Each object served as the target once in each block. Additionally, participants were also encouraged to point at the target object after the last label onset. Three no-label trials presented the cues in a neutral tone (*Look! Look at that! Look!*). Participants were not asked to point in the no-label trials because no target was specified.

Figure 3.1

An Example of Retention Phase in Experiment 2

RT1			
Trial Type	Stimuli	Associated Emotions	Target
Re-engagement		n/a	n/a
Label trial 1		negative-neutral	neutral
Label trial 2		negative-positive	negative
Label trial 3		positive-neutral	positive
No-label trial 1		neutral-negative	n/a
No-label trial 2		positive-neutral	n/a
No-label trial 3		negative-positive	n/a
Label trial 4		neutral-negative	negative
Label trial 5		neutral-positive	neutral
Label trial 6		positive-negative	positive

RT2			
Trial Type	Stimuli	Associated Emotions	Target
Re-engagement		n/a	n/a
Label trial 1		positive-negative	positive
Label trial 2		neutral-negative	negative
Label trial 3		neutral-positive	neutral
No-label trial 1		positive-negative	n/a
No-label trial 2		negative-neutral	n/a
No-label trial 3		neutral-positive	n/a
Label trial 4		positive-neutral	positive
Label trial 5		negative-neutral	neutral
Label trial 6		negative-positive	negative

Thus, each retention phase consisted of a total of six label trials and three no-label trials. Object pairings and left-right combinations were Latin square counterbalanced. Trial order was pseudorandomised within blocks to ensure the target object was presented on the same side in no more than two consecutive trials and the objects in the first no-label trial were not targets in the previous label trial. Label and neutral cue onsets on each retention trial were at 2000 ms, 4000 ms and 6000 ms from the beginning of a trial; the trial length was 8000 ms.

3.2.3 Data Cleaning and Model Selection

As in Chapter 2, trials in which participants' looking was less than 50% of the trial duration were excluded from analyses. 311 out of 333 trials were included for the analyses of the referent selection phase (93.39%); 235 out of 333 trials for RT1 (70.57%), and 239 out of 333 trials for RT2 (71.77%). Toddlers' pointing in the label trials was recorded by the experimenter. Pointing was coded as the first point location (left, right) after the third label onset. Points from 37 toddlers who pointed on more than two trials in each retention phase entered analyses (398 trials). A second coder, naïve to the experimental hypotheses, additionally coded 50% of the recordings for toddlers' pointing. Intercoder reliability was high (Cohen's Kappa: .89). The approach to report Bayes factors and effect size of analyses as well as model selection was in line with the approach described in Chapter 2.

3.3 Results

For the referent selection phase, to further confirm 30-month-old toddlers' looking patterns when learning novel label-object associations under different emotions, we again report toddlers' proportion face looking (looking to face AOI / looking to all four AOIs) and target looking among three objects (looking to target AOI / looking to three object AOIs) following the first label onset until the trial end. For the label trials in the retention phases, we analysed toddlers' proportion target looking (looking to target AOI / looking to both AOIs) and pointing data to test whether participants retained label-object associations; for the no-label trials, we analysed toddlers' proportion object looking (looking to one object AOI / looking to both AOIs) to explore the implicit effect of object emotionality on visual attention.

3.3.1 Referent selection

Thirty-seven out of 40 participants' eye tracking data entered the analyses of the referent selection phase after data cleaning. Data from three participants were removed because their looking was less than 50% on every trial.

Proportion Face Looking. To investigate toddlers' proportion face looking across labelling affect, we submitted proportion face looking to a LMEM with a fixed effect of affect. The best-fitting random effects structure included by-item, by-affect random intercepts and by-participant random slopes for affect ($\chi^2(5) = 29.58$, $p < .001$). Toddlers' looking to the actress' face after label onset differed according to labelling affect in referent selection trials ($\chi^2(2) = 18.34$, $p < .001$, $R^2_m = .08$, $R^2_c = .57$). Compared with the proportion face looking in the neutral referent selection trials ($M = 0.55$, $SD = 0.16$), looking in the negative referent selection trials was greater ($M = 0.65$, $SD = 0.19$; $\beta = 0.14$, $SE = 0.03$, $z = 3.57$, $p = .001$); but similar in the positive referent selection trials ($M = 0.55$, $SD = 0.15$; $\beta = 0.004$, $SE = 0.02$, $z = 0.19$, $p = .98$, $BF_{01} = 6.59$). The proportion face looking in the negative referent selection trials was greater than that of positive trials ($\beta = 0.10$, $SE = 0.02$, $z = 4.21$, $p < .001$).

Proportion Target Looking among Objects. To investigate proportion target looking across three labelling affects, we submitted proportion target looking to a LMEM with a fixed effect of affect and by-item, by-participant random intercepts, and by-participant random slopes for affect ($\chi^2(5) = 12.93$, $p = .02$). Toddlers' proportion target looking was similar across labelling affect ($\chi^2(2) = 4.24$, $p = .12$, $R^2_m = .03$, $R^2_c = .37$, $BF_{01} = 0.46$; neutral: M = 0.76, SD = 0.17; positive: M = 0.83, SD = 0.19; negative: M = 0.80, SD = 0.17).

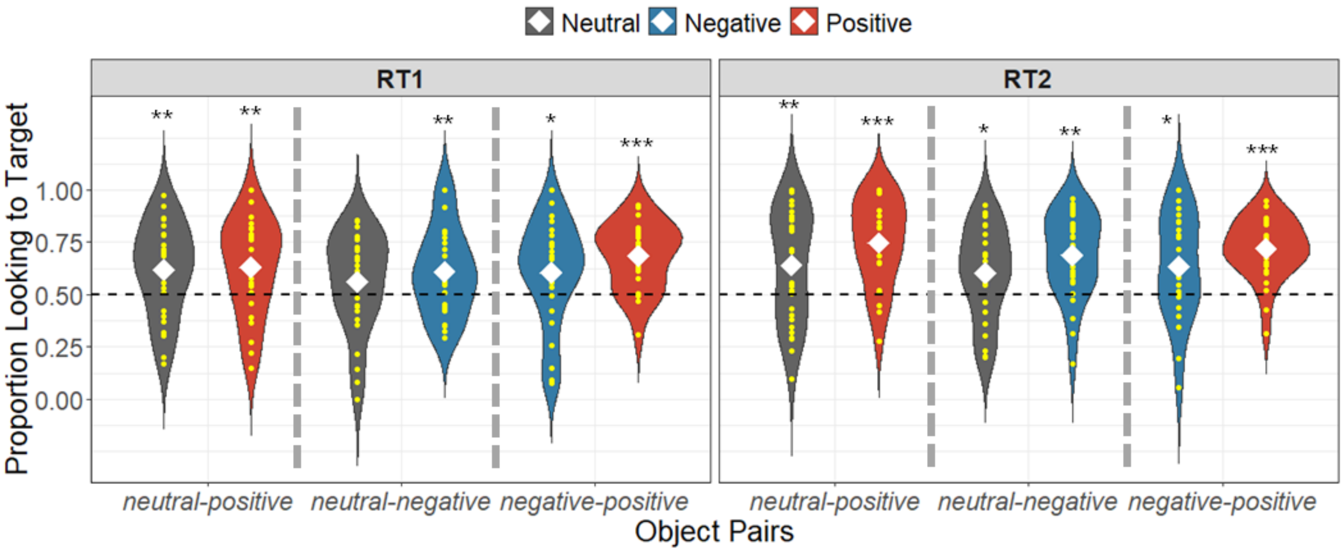
Therefore, in the referent selection phase, similar to the results reported in Chapter 2, toddlers looked to the neutral face the least, and the negative face the most, and did not show different target looking among the three target objects across labelling affect.

3.3.2 Retention

After data cleaning, data from 37 participants entered the analyses for RT1 and 36 entered the analyses for RT2. Proportion looking to a given object was again calculated across the 6500 ms time window after the first label onset. For label trials, proportion looking to the target was compared against chance (.50) using one-sample *t*-tests (two tailed; see Figure 3.2), as was proportion looking to each object in each object pair in the no-label trials (Figure 3.3). Pointing from 36 participants collected in the label trials entered the analyses for RT1 and 37 entered the analyses for RT2. Points to the target or distractor on each label trial were compared with random pointing (.50) by binominal test. We coded points as *target* and *positive/negative/neutral distractor* (Table 3.1).

Figure 3.2

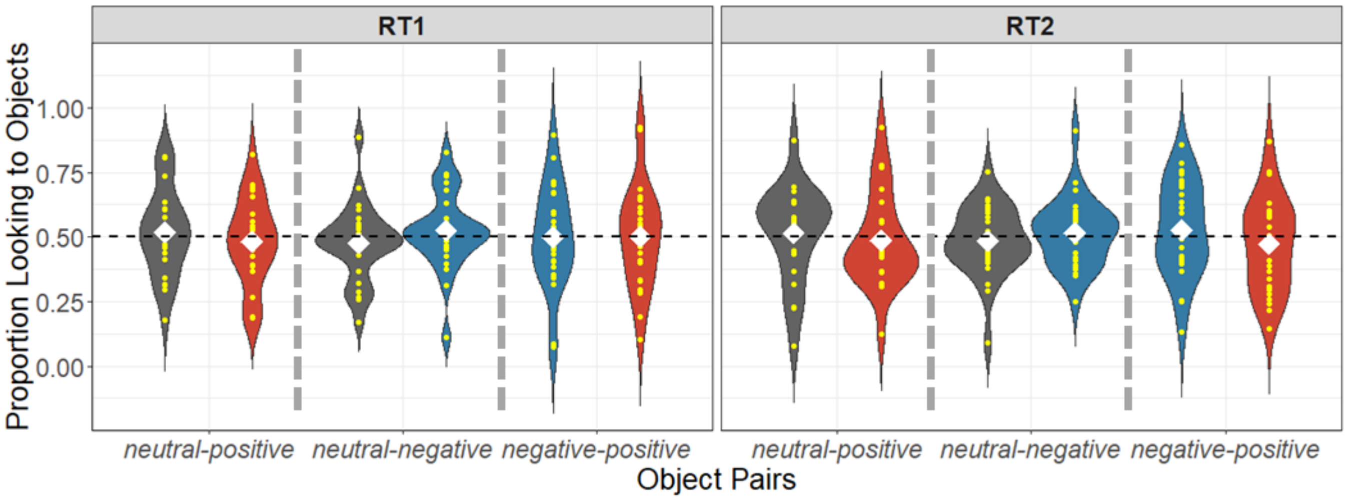
Proportion Looking Time to Targets in Label Trials in the Retention Phases



Note. White diamonds indicate the means of proportion target looking. The dashed line represents chance (0.50). $^{***}p < .001$; $^{**}p < .01$; $^{*}p < .05$.

Figure 3.3

Proportion Looking Time to Objects in No-label Trials in the Retention Phases



Note. White diamonds indicate the means of proportion target looking. The dashed line represents chance (0.50). $^{***}p < .001$; $^{**}p < .01$; $^{*}p < .05$.

Table 3.1

Binominal Test of Toddlers' Target Pointing in Label trials

Object pair	RT1			RT2		
	Target n (*N*)			Target n (*N*)		
	Neutral	Positive	Negative	Neutral	Positive	Negative
Neutral-positive	23 (29) **	27 (33) ***	-	29 (36) ***	29 (33) ***	-
Neutral-negative	27 (34) ***	-	24 (32) **	30 (35) ***	-	29 (36) ***
Negative-positive	-	27 (29) ***	26 (31) ***	-	29 (36) ***	27 (34) ***

Note. *N* is the total number of toddlers who pointed in a trial. *n* is the number of toddlers who pointed to the target.

*** $p < .001$; ** $p < .01$; *$p < .05$.

Label Trials in RT1. Apart from the neutral target in the *neutral-negative* pairs, toddlers looked all targets at above chance level, although they pointed to the neutral target in the *neutral-negative* pairs.

Neutral-positive Pairs. Toddlers looked and pointed to neutral and positive objects when they are targeted in the *neutral-positive* pair respectively (neutral object as target: $M = 0.62$, $SD = 0.22$, $t\ (27) = 2.88$, $p = .008$, $d = 0.54$; 23 out of 29 toddlers pointed to neutral targets, above chance; positive object as target: $M = 0.63$, $SD = 0\ .23$, $t\ (23) = 2.96$, $p = .01$, $d = 0.56$; 27 out of 33 toddlers pointed to positive targets, above chance).

Neutral-negative Pairs. Toddlers looked and pointed to negative objects, but only pointed to neutral object when they are targeted in the *neutral-negative* pair (neutral object as target: $M = 0.56$, $SD = 0.23$, $t\ (29) = 1.43$, $p = .16$, $d = 0.26$, $BF_{01} = 2.06$; 27 out of 34 pointed to neutral targets, above chance; negative object as target: $M = 0.61$, $SD = 0.21$, $t\ (29) = 2.89$, $p = .007$, $d = 0.53$; 24 out of 32 toddlers pointed to the targets, above chance).

Negative-positive Pairs. Toddlers looked and pointed to positive and negative objects when they are targeted in the *negative-positive* pair respectively (positive object as target: M = 0.68, SD = 0 .16, t (23) = 5.60, $p < .001$, d = 1.1; 27 out of 29 toddlers pointed to the positive target, above chance; negative object as target: M = 0.60, SD = 0.25, t (25) = 2.11, p = .045, d = .41; 26 out of 31 toddlers pointed to negative targets, above chance).

Additionally, the emotionality of the distractor did not affects toddlers' proportion target looking in RT1, revealed by a LMEM with an interaction of affect (neutral, positive, negative) and object pairs (*neutral-positive*, *neutral-negative*, *negative-positive*) and random intercepts for items and participants ($\chi^2(5) = 4.66$, $p = .46$, $R^2_m = .03$, $R^2_c = .12$, BF_{01} = 18184.62).

Label Trials in RT2. Toddlers looked and pointed to all targets for all the object pairs at above chance level.

Neutral-positive Pairs. Toddlers looked and pointed to neutral and positive objects when they are targeted in *neutral-positive* pair respectively (neutral object as target: M = 0.64, SD = 0.27, t (29) = 2.91, p = .007, d = .53; 29 out of 36 toddlers pointed to the neutral target, above chance; positive object as target: M = 0.75, SD = 0 .21, t (21) = 5.49, $p < .001$, d = 1.17; 29 out of 33 toddlers pointed to positive targets, above chance).

Neutral-negative Pairs. Toddlers looked and pointed to neutral and negative objects when they are targeted in *neutral-negative* pair respectively (neutral object as target, M = 0.60, SD = 0.22, t (24) = 2.34, p = 0.02, d = .47; 30 out of 35 toddlers pointed to the neutral target, above chance; negative object as target: M = 0.69, SD = 0.20, t (28) = 5.06, $p < .001$, d

= .94; 29 out of 36 toddlers pointed to neutral and negative targets, above chance).

Negative-positive Pairs. Toddlers looked and pointed to positive and negative objects when they are targeted in *negative-positive* pair respectively (positive object as target: M = 0.72, SD = 0.14, t (29) = 8.29, p < .001, d = 1.51; 29 out of 36 toddlers pointed to the positive target, above chance; negative object as target: M = 0.64, SD = 0.25, t (23) = 2.62, p = .02, d = .53; 27 out of 34 toddlers pointed to negative targets, above chance).

As in RT1, the emotionality of distractors did not affects toddlers' proportion target looking in the RT2, revealed by a LMEM with an interaction of affect and object pairs and random intercepts for items and participants ($\chi^2(5) = 9.91$, p = .08, $R^2_m = .05$, $R^2_c = .21$, BF_{01} = 352.54).

Overall, the results of label trials indicated that apart from toddlers did not looking to the neutral objects when they served as targets in the *neutral-negative* pairs in RT1, toddlers looked and pointed to targets in all the label-object associations in both retention phases.

No-label Trials. Overall, after hearing the neutral cues in the no-label trials, toddlers did not look systematically to any of the objects in each object pair in both retention phases.

RT1. Toddlers looked to neither neutral nor positive object in *neutral-positive* pairs (neutral: M = 0.52, SD = 0.17; positive: M = 0.48, SD = 0.17, t (22) = -0.51, p = 0.61, d = 0.11, BF_{01} = 4.05). Neither did them look to neutral nor negative object in *neutral-negative* pairs (neutral: M = 0.47, SD = 0.15; negative: M = 0.52, SD = 0.15, t (24) = 0.81, p = 0.42, d = 0.16, BF_{01} = 3.51). Neither did them in look to positive nor negative object in *negative-positive* pairs (positive: M = 0.50, SD = 0.20; negative: M = 0.50, SD = 0.20, t (22) = -0.04, p

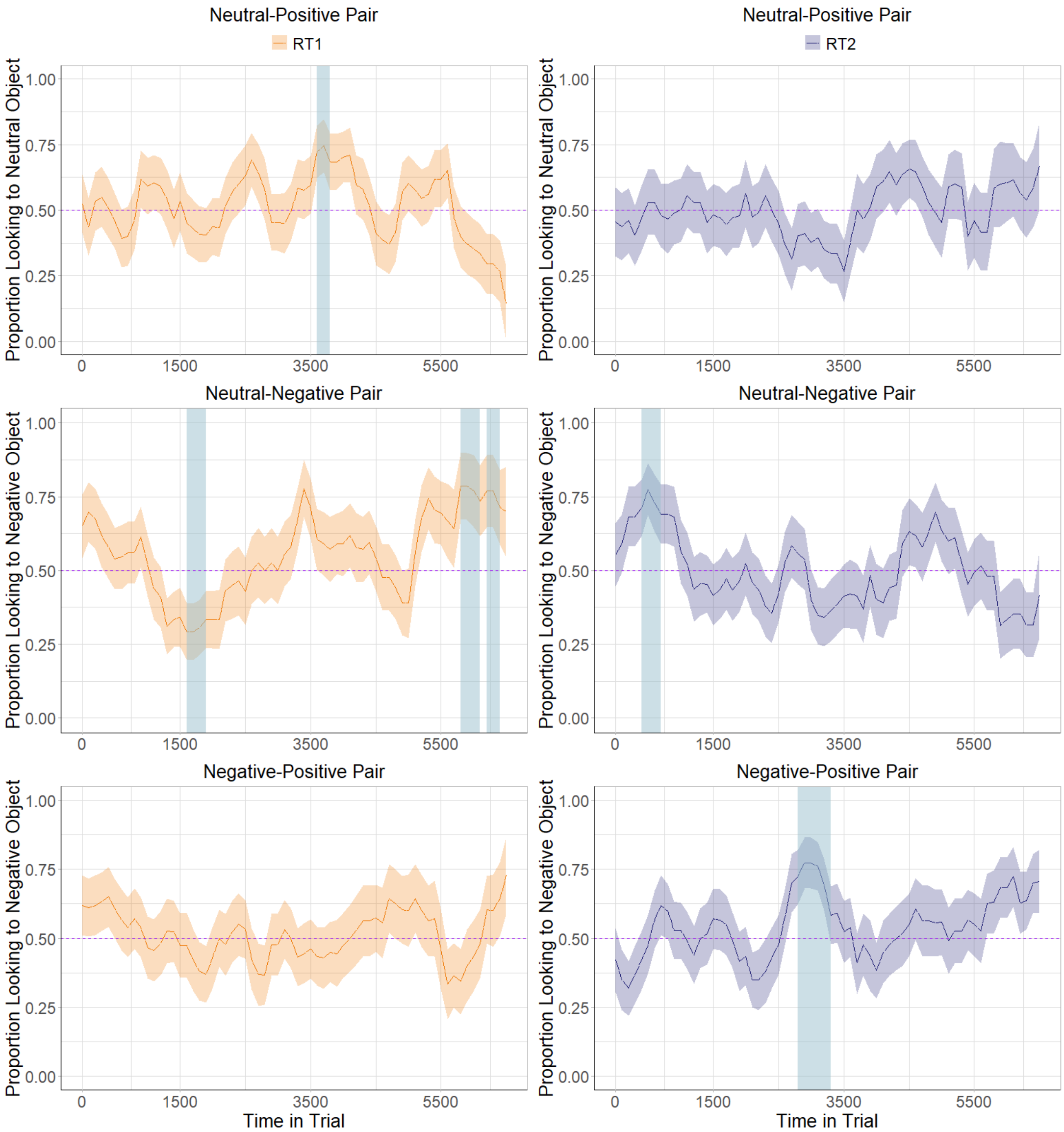
= 0.97, $d = 0.007$, $BF_{01} = 4.57$).

RT2. As in RT1, toddlers did not show any overall looking preference to any object in any object pair (for *neutral-positive* pairs, neutral: $M = 0.51$, $SD = 0.19$, positive: $M = 0.49$, $SD = 0.19$, t (20) = -0.34, $p = 0.74$, $d = 0.07$, $BF_{01} = 4.17$; for *neutral-negative* pairs, neutral: $M = 0.48$, $SD = 0.13$, negative: $M = 0.51$, $SD = 0.13$, t (26) = 0.60, $p = 0.56$, $d = 0.11$, $BF_{01} =$ 4.17; for *negative-positive* pairs (positive: $M = 0.47$, $SD = 0.18$; negative: $M = 0.53$, $SD =$ 0.18, t (26) = 0.78, $p = 0.44$, $d = 0.15$, $BF_{01} = 3.73$).

Time Series Analysis of No-label Trials. Because the overall proportion object looking time in the no-label trials revealed little information in terms of toddlers' detailed looking patterns, we calculated toddlers' proportion object looking time for every 100 ms time bin for each object pair (Twomey et al., 2017). We reported the proportion object looking to neutral object in *neutral-positive* pair and to negative object in *neutral-negative* and *negative-positive* pairs alongside the time course to explore toddlers' detailed looking patterns and examine the hypothesis that negative object might grab more visual attention (Figure 3.4). The time series analysis started from 1500 ms before the first cue onset (500 ms after the trial onset when two novel objects stayed still on the screen). Thus, the three cue onsets were at 1500 ms, 3500 ms, and 5500 ms. Proportion target looking for every 100 ms time bin was compared with chance (.50) using one sample *t*-tests (two tailed) to examine whether toddlers exhibited periods of above-chance looking. Then a bootstrapped cluster-based permutation analysis (bootstrapped samples: 2000) was employed to examine the probability (%) of obtaining a statistically significant results, a probability higher than 15% for at least 200 ms was suggested as a reliable reference that toddlers processed the objects (Dink & Ferguson, 2015; Maris & Oostenveld, 2007; Wendt et al., 2014).

Figure 3.4

Proportion Object Looking Time in 100 ms Time Bins in No-label Retention Trials



Note. The dashed line represents chance (.50). The light blue shadow represents the time bins during which proportion object looking time differed from chance ($p < .05$). The cue (*look!*) onsets were at 1500 ms, 3500 ms and 5500 ms respectively.

In RT1, after hearing (neutral) cues, toddlers looked to the neutral object in the *neutral-positive* pairs (3600 – 3800 ms); while in the *neutral-negative* pair, they looked both to the neutral object (1600 – 1900 ms) and, later, to the negative object (5800 – 6100 ms; 6200 – 6400 ms). In the *negative-positive* pair, toddlers' proportion looking to both negative and positive objects was at chance across the entire time course.

In RT2, in the *neutral-positive* pairs, toddlers showed no looking preference to either object; in the *neutral-negative* pair, they looked to the negative object (400 – 700 ms); and in the *negative-positive* pair, they looked to the negative object (2800 – 3300 ms).

Overall, by hearing only the neutral cues, apart from in the *negative-positive* object on the first day, toddlers looked to the negative object when it was displayed on the screen.

3.4 Discussion

The current experiment first, clarifies whether toddlers' failure to recognise positive label-object associations in Chapter 2 was because of a lack of retention or the influence of salient distractors. The results supported the latter interpretation: with only one distractor present, toddlers consistently looked and pointed at the positive target at above chance levels. Thus, in the experiment in Chapter 2, the presence of a salient negative distractor drew the toddlers' attention away from the target sufficiently to result in non-significant target looking. Second, we also examined whether toddlers' visual attention to paired objects was influenced by the negative emotion associated with them. Although toddlers' overall proportion looking provided little information, their detailed looking pattern over the time course of each trial shed some light on the how toddlers' visual attention varied in terms of the emotionally conditioned objects they perceived. Thus, we first discuss the findings of word learning outcome based on the effect of negative distractors on toddlers' visual attention after it was removed from the testing trials in the current experiment. Then, we discuss toddlers' looking to affectively negative conditioned objects when hearing neutral cues.

The finding here that toddlers retained positive label-object associations provides evidence that in Chapter 2 the negative distractor interfered with target looking, which was also the case when the neutral object was the target. In accordance with the results reported in Chapter 2, even though pointing showed that toddlers had retained the neutral label-object association on the first day, toddlers' looking to it was at chance. This finding suggests that, in terms of looking, there existed a competition between the named target and the salient distractor. As described in bias competition theories of attention, the sensory inputs compete for attention via bottom-up sensory-driven mechanisms and top-down influences (Kastner & Ungerleider, 2001; Yiend, 2010). In the current case, seeing the novel objects and hearing the auditory stimuli (labels, neutral cues) activated bottom-up attentional processes, while identifying the referents of the heard labels constituted a top-down attentional process. Thus, a competition for attention arose in terms of distractor salience, determined by object emotionality, and target salience, evoked by the heard labels. Attending to the target required inhibition of the salience effect, which is mediated by the neural network in frontal and parietal area (Kastner & Ungerleider, 2001). The fact that toddlers were less able to disengage their attention from the negative distractor when identifying the neutral target might be due to toddlers' still developing frontal and parietal areas (Giedd et al., 1999).

However, when toddlers came back for the second test on the second day, they fixated the neutral target above chance even when the negative distractor was presented alongside. This finding indicates two possible accounts: one is that the target salience was strengthened and outweighed the distractor salience during retrieval on the second day. Alternatively, as time passed, the attraction effect of the negative distractor on visual attention might have declined on the second day. Regarding the first account, empirical evidence shows that frequent naps and overnight sleep promote early word learning through memory consolidation (Horváth et al., 2016; Williams & Horst, 2014). Likewise, in the current study the newly learned label-object associations could have been consolidated by the overnight sleep between the two tests. However, studies investigating sleep-based memory consolidation also indicate that, compare with emotionally neutral objects, emotionally negative objects are more likely to be memorised and retrieved after an overnight sleep (Payne & Kensinger, 2011). Accordingly, the negative emotion-object associations in the study should also be consolidated and have an impact on visual attention even on Day 2. Thus, the second account provides another perspective to interpret toddlers' looking patterns between the two tests. Considering the argument from an adult study that processing a salient distractor (emotional facial expressions) and recognising the target (name-face pairs presented on the screen) are two independent cognitive processes and that the perceived facial expressions had little impact on the recognition of name-face associations over time (Tsukiura et al., 2003), we suggest that, on the second day, hearing the labels promotes the recognition of referents visually. Overall, given the two accounts, over time, although the negatively trained object continued to compete for visual attention, the facilitation of perceived labels increases whereas the salience of the negative object wanes.

Without labelling, the no-label trials examined the salience of the negative object, that is, the implicit effect of objects with negative emotionality on toddlers' looking. Unlike in Chapter 2 where we employed three affective cues, in the current experiment, only neutral cues were used in the no-label trials. Based on the overall proportion looking, we found no looking preference for any objects. This result may be due to the change from three to two objects, which altered toddlers' looking during the task. Since, compared with presenting two distractors, in the presence of a single distractor the chance level increased from .33 to .50, toddlers must sustain longer looking to demonstrate above chance overall looking time. As a result, the presentation of two objects may not be sensitive enough to measure the impact of object emotionality on visual attention. Therefore, the time series analyses helped to illustrate toddlers' looking in terms of objects' emotionality. As we assumed, the negative object captured toddlers' visual attention no matter whether it was paired with neutral or positive objects, suggesting the negative object is the most visually salient object among the three affectively conditioned objects. In contrast, the positive object, which was also emotionally conditioned, did not have a similar effect on toddlers' looking. This result is not surprising as previous evidence from ERP studies suggests that infants only show enhanced attention towards objects associated with negative affect rather than objects associated with neutral or positive affect in an immediate test (e.g., Hoehl, Palumbo, et al., 2008; Hoehl & Striano, 2010a; Hoehl, et al., 2008). Thus, the current findings may provide the first evidence that toddlers' visual attention is implicitly attracted by the object with negative emotionality.

Notably, even though toddlers' looking to neutral object was unsystematic, there is also a possible top-down control of visual attention induced by the neutral cues in the current no-label trials. By learning the neutral label-object association in the neutral labelling affect, toddlers might associate the neutral affect with the neutral object. Thus, hearing only the neutral cues in the no-label trials might also activate a competition for visual attention between the neutral object and the distractors. As revealed in the results, after hearing neutral cues, toddlers looked to the neutral object when paired with positive object on the first day, further confirming that object with positive emotionality does not capture toddlers' attention (Hoehl & Striano, 2010a). Moreover, on the second day, toddlers disengaged their visual attention from the negative object after hearing the neutral cues, suggesting that hearing the neutral cues activated the top-down control. Overall, we argued that the negativity bias exists and affects toddlers' visual attention implicitly, hearing the neutral cues activates toddlers' top-down attentional control. Consequently, their looking patterns was the outcome of competition for visual attention between object emotionality.

In sum, toddlers' failure to recognise the positive label-object association in Chapter 2 was because of the salience of negative distractor on toddlers' visual attention. Thus, although 30-month-olds' looking patterns is the result of competition between target salience and distractor salience, they still retained all three label-object associations regardless of the perceived emotions during learning. Moreover, we also confirmed that the newly learned negative objects grabbed toddlers' visual attention. All in all, learning label-object associations in the emotional contexts shapes the attributes of objects, such as the labels and emotionality attached to them. At test, the linguistic cues, the heard labels or neutral cues, activate toddlers' top-down attentional control to identify the referents, while the negative emotionality of objects affects toddlers' attention implicitly by attracting their looking to the negative object.

Chapter 4: The Impact of Perceived Emotions on Early Word Learning in 24- and 36-month-old Children: Developmental Change in Attentional Processing in Retention

4.1 Introduction

Taken together, the findings in Chapters 2 and 3 suggest that labelling affect has little impact on the retention of label-object associations in 30-month-olds, but that toddlers' visual attention during the learning process and recognition is affected by the negative distractors. However, as we found in Chapter 2, unlike toddlers, adults' visual attention was not affected by the negative object during the retrieval of both label-object and emotion-object associations. Furthermore, adults could associate emotional cues with the object and further used mutual exclusivity to link the neutral cue with the neutrally conditioned object, suggesting that associating affective cues with the corresponding objects requires not only better memory but also more mature, top-down attentional control to sustain their looking on the targets and supress the negativity bias. Although we found the negativity bias in toddlers' visual attention, it remains unclear whether they were able to associate the affective cues with objects, which reflects the strength of the perceived cues (labels and emotions) in terms of recognition. Meanwhile, it is still unknown when the top-down control, the ability to overcome the impact of the negativity bias on visual attention during recognition and to sustain looking to the target object, emerges and develops. In the current chapter, we address these questions by examining the retention of label-object and emotion-object associations in toddlers of different ages and exploring the development of top-down attentional control.

Multiple studies have reported that toddlers over 18 months old are able to map a novel label to a novel object (e.g., Akhtar & Tomasello, 1996; Horst & Samuelson, 2008), but that the *retention* of these label-object association is poor in the referent selection and retention paradigm (Horst & Samuelson, 2008). Even though 18-month-old toddlers can recognise novel label-object associations at least from short-term memory based on facial expressions (positive or negative) displayed by an experimenter in an object searching paradigm (Tomasello et al., 1996), in the referent selection and retention paradigm with no social and emotional cues involved, 24-month-old toddlers' retention of the new learned associations was poor after a five-minute delay (Horst & Samuelson, 2008). Thus, in the present study we chose 24-month-old toddlers as the younger age group to examine whether learning novel label-object associations in emotional contexts facilitates retention.

Furthermore, to explore the development of top-down control to restrain the negativity bias during retrieval, we recruited 36-month-old toddlers as the older age group in the current experiment. On one hand, the 30-month-olds in the previous experiments retained the label-object associations but were not able to completely override the negativity bias during recognition, indicating that top-down control is developing at this age. On the other hand, 36-month-old toddlers have been found to retain new-learned label-object associations robustly after a delay following a challenging referent selection task with novel competitors (Axelsson & Horst, 2014). In the present study, if the 36-month-old toddlers would show retention through above-chance target looking for newly learned label-object and emotion-object associations, like the adults reported in the Chapter 2, we could assume that the top-down control of the effect of negativity bias on visual attention would have been developed at that age. Therefore, the neutral, positive, and negative cues would be employed in the no-label trials to examine the retention of emotion-object associations and address this possibility in the current experiment.

Based on the previous findings that the 36-month-olds successfully retained newly learned label-object associations (Axelsson & Horst, 2014), we hypothesised that the 36-month-olds would retain all the label-object associations. Meanwhile, considering that 18-month-olds are able to map a novel label to its referent when social interaction is involved in the object searching task (Tomasello et al., 1996) and the enhancement of perceived negative affect in terms of attention (e.g., Carretié et al., 2001; Carver & Vaccaro, 2007), we assumed that 24-month-olds might retain the negative label-object associations. Moreover, both age groups might also retain the negative emotion-object association. Exploring the retention of neutral and positive emotion-object associations in both age groups was planned to gain additional insights into the development of top-down control of restraining the impact of negative distractors on visual attention and maintaining looking on the targets.

4.2 Method

4.2.1 Participants

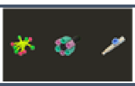
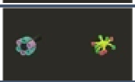
Sixteen 23 to 25-month-old (24-month-olds) and twenty-eight 35- to 37-month-old (36-month-olds) typically developing British monolingual English-learning toddlers participated in the study (24-month-olds: 7 girls, *M* = 756.19 days, *SD* = 14.57 days; range = 732–786 days; 36-month-olds: 13 girls, *M* = 1111.46 days, *SD* = 21.43 days; range = 1076–1152 days). An additional 14 toddlers were excluded from analyses for failure to remain on the caregiver's lap (8); caregiver intervention (1); eye tracker error (4); and experimenter error (1). Toddlers' mean productive vocabulary for 24-month-olds was 310.25 (*SD* = 146.97, range = 59 – 586) and for 36-month-olds was 586.54 (*SD* = 68.55, range = 422 – 681), as measured by the Lincoln Toddler Communicative Development Inventory (Meints et al., 2017). Caregivers gave consent to participate and received travel reimbursement. Toddlers were given a story book for taking part. Data collection for the current experiment ceased because of the COVID-19 pandemic: the number of participants was lower than the anticipated number (36 in each age group), which reflects testing all counterbalancing orders. Thus, we applied additional analyses to the available data, specified in the results part, to assure that the results reported in the current chapter reflect toddlers' looking patters as the result of perceived emotions instead of the effect of objects or not fully counterbalanced position in the testing phase. Notably, due to the insufficient number of participants in each age group, the statistical analyses conducted in the current experiment might be underpowered. But the Bayesian factors and the effect sizes of LMEMs and *t-tests* were also reported to reflect the statistical references of analyses.

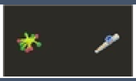
4.2.2 Procedure and design

Considering the second test on the second day was designed to examine the retention from the long-term memory but the toddlers showed retention of label-object associations on both days in the previous experiments, indicating no significant effect of time on retention, thus, the procedure of current experiment included only one retention phase with the rest of procedure remains identical: a referent selection phase was followed by a five-minute break, after which the retention phase took place. The presentation order of neutral, positive and negative blocks of the referent selection phase was the same as that reported in Chapter 3. In the current retention phase (Figure 4.1), two out of the three novel objects were presented on each trial. The retention phase consisted of four blocks: two blocks of three label trials were presented in the first and the third blocks, while two blocks of three no-label trials were presented in the second and fourth block. The same combination of the object pairs as in Chapter 3 were presented in each block: *neutral-positive*, *neutral-negative*, and *negative-positive*. In line with the label trials in previous experiments, the target was labelled three times in neutral affect on each label trial (e.g., *Can you find the coodle*? *Look at the coodle*! *Where is the coodle*?). Neutral, positive and negative cues were employed in the no-label trials; each affect was represented once in each block (neutral: *Look! Look at that! Look!* positive: *Wow! Look! Wow! Look at that! Wow!* negative: *Urgh! Look! Urgh! Look at that! Urgh!*).

Figure 4.1

An Example of Retention Phases in Experiment 3

RT			
Trial Type	Stimuli	Associated Emotions	Target
Re-engagement		n/a	n/a
Label trial 1		negative-neutral	neutral
Label trial 2		negative-positive	negative
Label trial 3		positive-neutral	positive
No-label trial 1		neutral-negative	neutral
No-label trial 2		positive-neutral	positive
No-label trial 3		negative-positive	negative
Attention Getter		n/a	n/a

Label trial 4		neutral-negative	negative
Label trial 5		neutral-positive	neutral
Label trial 6		positive-negative	positive
No-label trial 4		positive-neutral	neutral
No-label trial 5		negative-neutral	negative
No-label trial 6		positive-negative	positive

For both label and no-label blocks, each object served as the target once in each block in terms of the labelling affect associated with it, for example, for the blocks with label trials, if a neutral object in the *neutral-positive* pair was targeted in the first block, the positive object in the same pair would be the target in the third block; the same was true for the blocks with no-label trials. Thus, in the current experiment, the retention phase consisted of a total of six label trials and six no-label trials. Object pairings, left-right combinations, and order of the same type of blocks were Latin square counterbalanced. Trial order was pseudorandomised within blocks to ensure the target object was presented on the same side in no more than two consecutive trials and the objects in the first no-label trial were not targets in the previous label trial. In the retention trials, two novel objects slid in from the left bottom corner of the screen and stayed still after 500 ms from trial onset. Label and affective cue onsets on each retention trial were at 1500 ms, 3500 ms and 5500 ms from the moment that objects remained still on the screen; the trial length was 8000 ms.

Participants were not asked to point to the targets in either trial type in this experiment because 12 test trials with looking and pointing were demanding for both age groups. The first four toddlers (two 24-month-olds, two 36-moth-olds) who were asked to point to the target became fussy and struggled after completing the sixth, eighth and ninth testing trials respectively, which interfered with the data collection of the eye tracker. One of the four participants was excluded due to parent intervention (reported above).

4.2.3 Data Cleaning and Model Selection

As in previous experiments, trials in which participants' looking was less than 50% of the trial duration were excluded from analyses. 335 out of 396 trials were included for the analyses of the referent selection phase (84.60%); 171 out of 264 trials for the label test trials (64.77%), and 169 out of 261 trials for the no-label test trials (one participant only completed three no-label trials, 64.75%). The LMEM selection procedure was carried out in line with previous analysis.

4.3 Results

For the referent selection phase, we report toddlers proportion face looking (looking to face AOI / looking to all four AOIs looking) and proportion target looking (looking to target

AOI / looking to three object AOIs) following the first label onset until the trial end to uncover how labelling affect influenced their attention distribution to novel objects during learning in different age groups. For the retention phase, we analysed participants' proportion target looking (looking to target AOI / looking to all two AOIs) to test whether participants retained label-object and emotion-object associations differently based on the labelling affect associated with objects, and whether retention differed across the two age groups. We also report time series analyses of the two age groups in the retention phase to further illustrate the dynamics of toddlers' looking on testing trials.

4.3.1 Referent Selection

Proportion Face Looking in 24-Month-Olds. We first submitted proportion face looking to a LMEM with a fixed effect of affect. The best-fitting random effects structure included by-item, by-participant, by-affect random intercepts and by-participant random slopes for affect ($\chi^2(1) = 26.23$, $p < .001$). Toddlers' proportion face looking after label onset differed according to labelling affect ($\chi^2(2) = 55.35$, $p < .001$, $R^2_m = .24$, $R^2_c = .50$). Compared with the proportion face looking in the neutral referent selection trials ($M = 0.55$, $SD = 0.14$), that in the negative trials was greater ($M = 0.73$, $SD = 0.12$; $\beta = 0.19$, $SE = 0.03$, $z = 7.20$, $p < .001$); but similar to that in the positive trials ($M = 0.60$, $SD = 0.15$; $\beta = 0.05$, $SE = 0.03$, $z = 2.03$, $p = .07$, $BF_{01} = 1.44$). Proportion face looking in the negative trials was greater than that in positive trials ($\beta = 0.13$, $SE = 0.03$, $z = 5.27$, $p < .001$). The 24-month-olds spent the longest time looking to the negative face among three affective faces.

Proportion Target Looking in 24-Month-Olds. We then submitted proportion target looking to a LMEM with a fixed effect of affect and random effects of by-item, by-participant random intercepts. Toddlers' looking to the novel targets differed by affect ($\chi^2(2) = 6.82$, $p = .03$, $R^2_m = .06$, $R^2_c = .21$). Specifically, compared with looking to neutral targets ($M = 0.77$, $SD = 0.17$), toddlers looked more to negative targets ($M = 0.86$, $SD = 0.16$, $\beta = 0.10$, $SE = 0.04$, $z = 2.46$, $p = .04$) and at similar levels to positive targets ($M = 0.79$, $SD = 0.17$, $\beta = 0.02$, $SE = 0.04$, $z = 0.46$, $p = .89$, $BF_{01} = 3.97$). Toddlers' looking to positive and negative target was similar ($\beta = 0.08$, $SE = 0.04$, $z = 2.02$, $p = .11$, $BF_{01} = 0.58$). Overall, then, 24-month-old toddlers looked to the negative face the most, and to the negative targets more than neutral target in the referent selection phase.

Proportion Face Looking in 36-month-olds. We submitted proportion face looking to a LMEM with a fixed effect of affect. The best-fitting random effects structure included by-item, by-participant, by-affect random intercepts and by-participant random slopes for affect, ($\chi^2(1) = 16.56$, $p < .001$). Toddlers' proportion face looking after label onset differed according to labelling affect ($\chi^2(2) = 32.13$, $p < .001$, $R^2_m = .11$, $R^2_c = .49$). Compared with the proportion face looking in the neutral referent selection trials ($M = 0.51$, $SD = 0.16$), that in the negative trials was greater ($M = 0.65$, $SD = 0.16$; $\beta = 0.14$, $SE = 0.03$, $z = 5.50$, $p < .001$); but similar to that in the positive trials ($M = 0.54$, $SD = 0.20$; $\beta = 0.04$, $SE = 0.03$, $z = 1.61$, $p = .24$, $BF_{01} = 3.13$). Proportion face looking in the negative trials was greater than that of positive trials ($\beta = 0.10$, $SE = 0.03$, $z = 3.88$, $p < .001$). Thus, 36-month-old toddlers also spent the longest time looking to the negative face among three affective faces.

Proportion Target Looking in 36-month-olds. We then submitted proportion target looking to a LMEM with a fixed effect of affect, and of by-item, by-participant random intercepts. Toddlers' looking to the novel targets was similar across affects, ($\chi^2(2) = 4.42$, $p = .11$, $R^2_m = .03$, $R^2_c = .21$, $BF_{01} = 1.71$; neutral: $M = 0.78$, $SD = 0.19$; positive: $M = 0.82$, $SD = 0.16$; negative: $M = 0.85$, $SD = 0.15$). Thus, the 36-month-old toddlers looked to the negative face the most but looked to targets for similar amount of time across affects in the referent selection phase.

4.3.1.1 Comparison between Two Age Groups

Proportion Face Looking. The comparison of proportion face looking between age groups was analysed by a LMEM with dependent variable of proportion face looking, fixed effect of an interaction of affect and age group (24-month-old, 36-month-old), and by-item, by-participants and by-affect random intercepts ($\chi^2(1) = 30.36$, $p < .001$). This analysis revealed a significant interaction ($\chi^2(5) = 70.37$, $p < .001$, $R^2_m = .18$, $R^2_c = .51$). Planned Tukey's HSD tests indicated no differences of proportion face looking between the two age groups in the neutral and positive referent selection trials (neutral: $\beta = -0.05$, $SE = 0.04$, $z = -1.61$, $p = .84$, $BF_{01} = 2.00$; positive: $\beta = -0.05$, $SE = 0.04$, $z = -1.25$, $p = .79$, $BF_{01} = 1.39$), but the 36-month-olds looked less to the negative face than the 24-month-olds did indicated by Bayes Factor ($\beta = -0.09$, $SE = 0.04$, $z = -2.34$, $p = .16$, $BF_{01} = 0.08$).

Proportion Target Looking Among Objects. The comparison of proportion target looking between age groups was analysed by a LMEM with the dependent variable of proportion target looking, fixed effect of an interaction of affect and age group, and by-item, by-participants random intercepts. This analysis showed a significant interaction ($\chi^2(5)$ = 11.61, p = .04, R^2_m = .04, R^2_c = .17), but planned Tukey's HSD tests indicated no difference of proportion target looking between the two age groups (neutral: β = 0.01, SE = 0.03, z = 0.35, p = 1.00, BF_{01} = 4.41; positive: β = 0.04, SE = 0.03, z = 1.17, p = .85, BF_{01} = 2.75; negative: β = -0.02, SE = 0.03, z = -0.53, p = .99, BF_{01} = 4.60).

Overall, during referent selection, the difference between the two age groups was in the face looking in the negative referent selection trials: compared with 24-month-olds, the 36-month-olds looked less to the negative face in the learning phase.

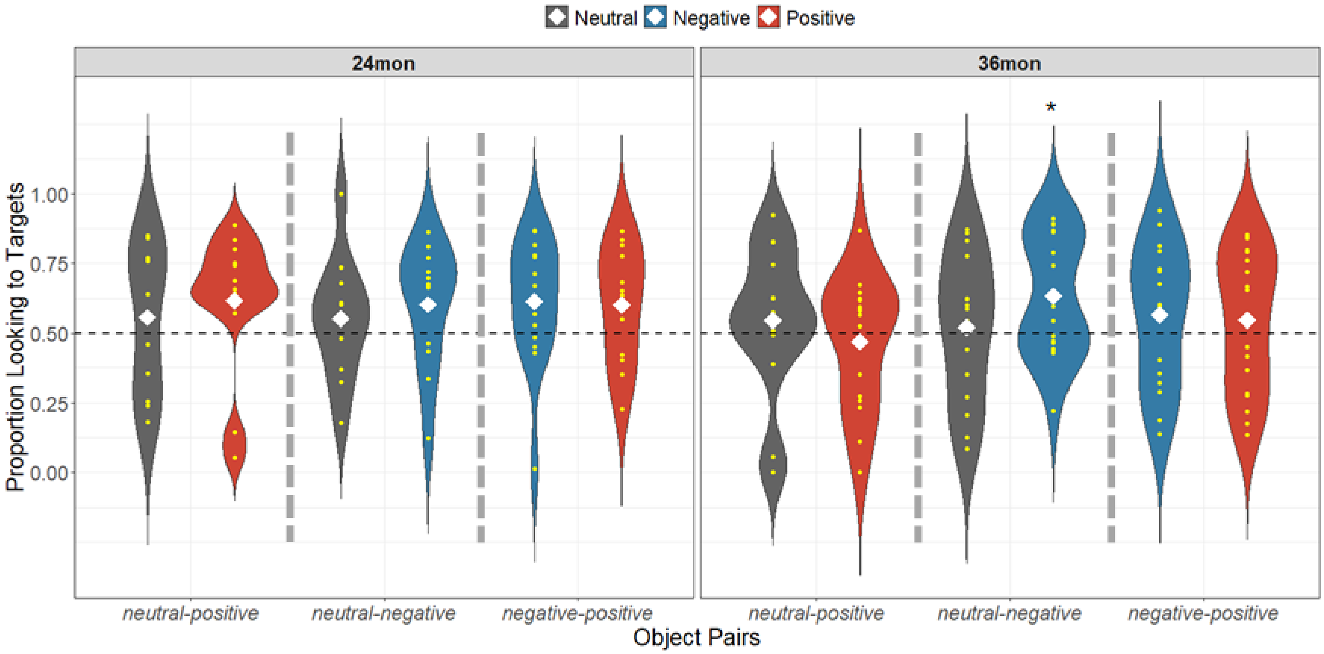
4.3.2 Retention

The retention of label-object and emotion-object associations was examined by comparing the overall proportion target looking with chance (.50) to reflect the sustained looking to targets in the testing trials. We also compared the proportion target looking in 100 ms time bin with the chance in the time series analyses to reflect toddlers' detailed looking patterns on the entire time course in the retention phase. Notably, the number of participants in both age groups was insufficient to fully counterbalance the object-emotion combinations and left-right positions in the retention phase across participants. Thus, the looking data may reflect an attentional bias due to the left-right position or characteristics of objects (Colombo, 2001) rather than the retention of label-object and emotion-object association or the implicit effect of new-learned emotionality of objects. Therefore, we examined whether the overall proportion target looking was affected by target objects and the position of the target.

LMEMs with an interaction between target object (*teebu, coodle, bosa*) and position (*left, right*) and random intercepts for items and participants for each age group in the label and no-label trials indicated no differences in proportion target looking across objects based on position in the label trials (24-month-old: $\chi^2(5) = 8.61$, $p = .13$, $R^2_m = .09$, $R^2_c = .28$, $BF_{01} = 119.22$; 36-month-old: $\chi^2(5) = 7.25$, $p = .20$, $R^2_m = .06$, $R^2_c = .22$, $BF_{01} = 85.20$) as well as in the no-label trials for both age groups (24-month-old: $\chi^2(5) = 10.07$, $p = .07$, $R^2_m = .14$, $R^2_c = .24$, $BF_{01} = 8127.72$; 36-month-old: $\chi^2(5) = 4.47$, $p = 0.22$, $R^2_m = .04$, $R^2_c = .22$, $BF_{01} = 33.21$). Thus, toddlers' overall proportion target looking was not affected by the not-fully counterbalanced position of object. Then, toddlers' proportion looking to a given object was calculated across the 6500 ms time window after the first label and cue onset. Both age groups' proportion target looking was compared against chance (.50) using one-sample *t*-tests (two tailed) for the label and no-label trials (Figure 4.2 & 4.6).

Figure 4.2

Proportion Looking Time to Targets in Label Trials for Two Age Groups



Note. White diamonds indicate the means of proportion target looking. The dashed line represents chance (0.50). $^{***}p < .001$; $^{**}p < .01$; $^{*}p < .05$.

4.3.2.1 Label Trials: Overall Proportion Target Looking

24-month-olds. For all object pairs, 24-month-olds' proportion target looking was at the level of chance (for *neutral-positive* pairs: neutral target, $M = 0.56$, $SD = 0.26$, t (10) = 0.71, p =.50, $d = 0.21$, $BF_{01} = 2.72$; positive target, $M = 0.62$, SD = 0 .25, t (12) = 1.70, $p = .11$, d = 0.47, $BF_{01} = 1.15$); for *neutral-negative* pairs: neutral targets, $M = 0.55$, $SD = 0.22$, t (10) = 0.75, $p = .47$, $d = 0.23$, $BF_{01} = 2.65$; negative targets, $M = 0.60$, $SD = 0.22$, t (11) = 1.62, p = .13, $d = 0.47$, $BF_{01} = 1.24$; for *negative-positive* pairs: negative targets, $M = 0.61$, SD = 0.23, t (13) = 1.83, $p = .09$, $d = 0.49$, $BF_{01} = 0.99$; positive targets: $M = 0.60$, $SD = 0.21$, t (11) = 1.67, $p = .12$, $d = 0.48$, $BF_{01} = 1.17$). They showed no differences in proportion target looking between the different affects across the object pairs, reaved by a LMEM with an interaction of affect (neutral, positive, negative) and object pairs (*neutral-positive*, *neutral-negative*, *negative-positive*) and random intercepts for items and participants ($\chi^2(5) = 1.45$, $p = .92$, $R^2_m = .02$, $R^2_c = .14$, $BF_{01} = 438.28$).

36-month-olds. The 36-month-olds' proportion target looking was above chance only for the negative target in the *neutral-negative* pairs but not for the objects targeted in the other pairings (for *neutral-positive* pairs, neutral targets: $M = 0.59$, $SD = 0.23$, $t\ (11) = 1.39$, $p = .19$, $d = 0.40$, $BF_{01} = 1.61$; positive targets: $M = 0.47$, $SD = 0.23$, $t\ (16) = -0.56$, $p = .58$, $d = -0.14$, $BF_{01} = 3.49$; for *neutral-negative* pairs, neutral targets: $M = 0.53$, $SD = 0.27$, $t\ (14) = 0.46$, $p = .65$, $d = 0.12$, $BF_{01} = 3.47$; negative targets: $M = 0.62$, $SD = 0.20$, $t\ (17) = 2.28$, $p = .04$, $d = .54$; for *negative-positive* pairs, positive targets: $M = 0.54$, $SD = 0.24$, $t\ (19) = 0.69$, $p = .50$, $d = 0.15$, $BF_{01} = 3.48$; negative targets: $M = 0.57$, $SD = 0.26$, $t\ (13) = 1.06$, $p = .06$, $d = .28$, $BF_{01} = 0.99$).

The 36-month-olds showed no differences in proportion target looking between the different affects across the object pairs either, revealed by a LMEM with fixed effect of an interaction of affect and object pairs and random intercepts for items and participants ($\chi^2(5) = 5.25$, $p = .39$, $R^2_m = .05$, $R^2_c = .23$, $BF_{01} = 476.52$).

Comparison Between Age Groups. No difference in proportion of target looking was found between the two age groups in terms of affect and object pairs, revealed by a LMEM with an interaction of age group, affect and object pairs and random intercepts for items and participants ($\chi^2(11) = 7.67$, $p = .74$, $R^2_m = .04$, $R^2_c = .20$, $BF_{01} = 12521.68$).

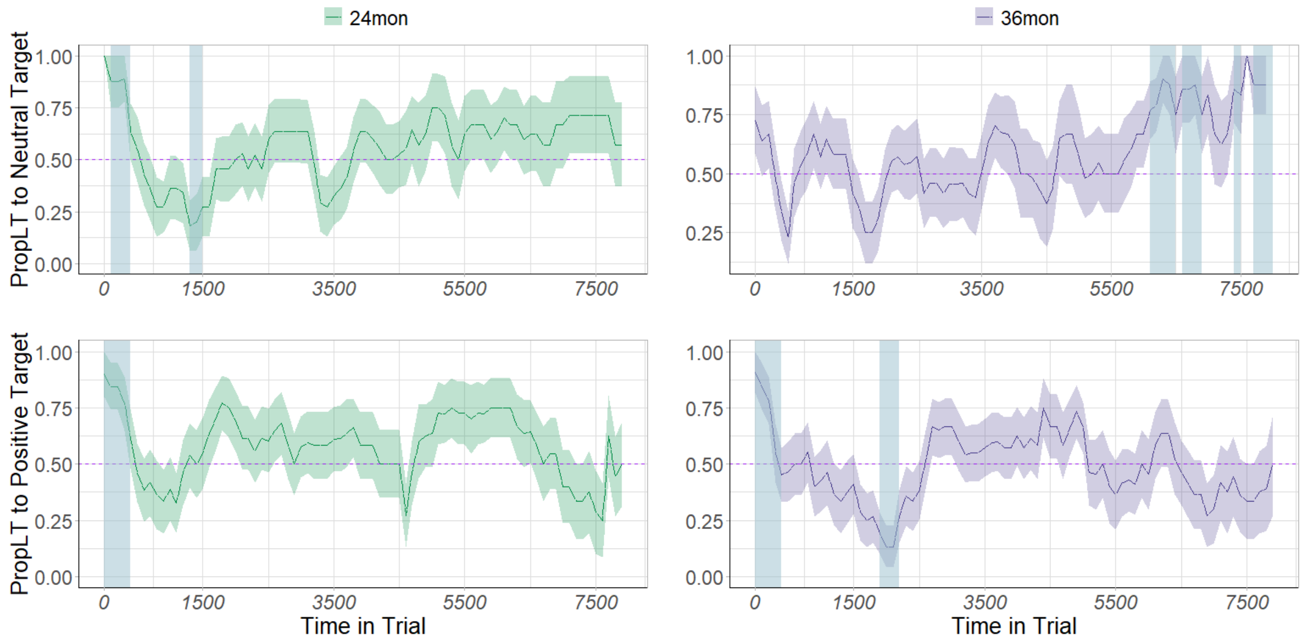
Overall, apart from 36-month-old toddlers demonstrating above chance overall proportion target looking to negative targets when paired with a neutral distractor, neither age group showed above chance overall proportion target looking for any object pairs.

4.3.2.2 Label Trials: Time Series Analyses of Proportion Target Looking

Like the time bin analyses reported in Chapter 3, to illustrate the dynamics and detail of toddlers' looking patterns, we analysed their proportion target looking time for every 100 ms time bin starting from 1500 ms before the first cue onset when the two novel objects stayed still on the screen until the trial end. Thus, the label onsets reported in the time series analyses occurred at 1500 ms, 3500 ms and 5500 ms. Proportion target looking for each 100 ms time bin was compared with chance (.50) using a one sample *t*-test. Then a bootstrapped cluster-based permutation analysis (bootstrapped samples: 2000) was employed to examine the probability (%) of obtaining a statistically significant effect (alpha was .05); a probability higher than 5% for at least 200 ms was suggested as a reliable indicator that toddlers processed the stimuli (Dink & Ferguson, 2015; Maris & Oostenveld, 2007; Wendt et al., 2014). Figures 4.3 – 4.5 present proportion target looking for each object pair. Additionally, we compared proportion target looking in terms of position (left and right) for the pre-label and pre-cue period during which the time bins revealed statistically significant differences in looking times as post-hoc analyses to examine whether toddlers' pre-label and pre-cue looking were due to the not fully counterbalanced left-right position of objects.

Figure 4.3

Label Trials: *Proportion Target Looking in the Neutral-Positive Pair*



Note. The dashed line represents chance (0.50). The light blue shadow represents the time bins during which proportion target looking time is different from chance ($p < .05$). The label onsets were at 1500 ms, 3500 ms and 5500 ms respectively.

Examination of Position Bias. To verify whether the attentional bias was due to the position of objects in the pre-label period, we employed a post-hoc independent *t*-tests to compare the pre-label proportion looking from 0 to 600 ms of the time course in terms of left and right position in the trials in which toddlers' target looking was significantly different from chance. The interval of 0 – 600 ms includes the period indicating significant results in those trials. For the 24-month-old toddlers, the target objects were all on the left side in the trials that presented the *neutral-positive* pair; in the *neutral-negative* pair, the pre-label proportion looking was different between left and right position (left: $M = 0.82$, $SD = 0.16$;

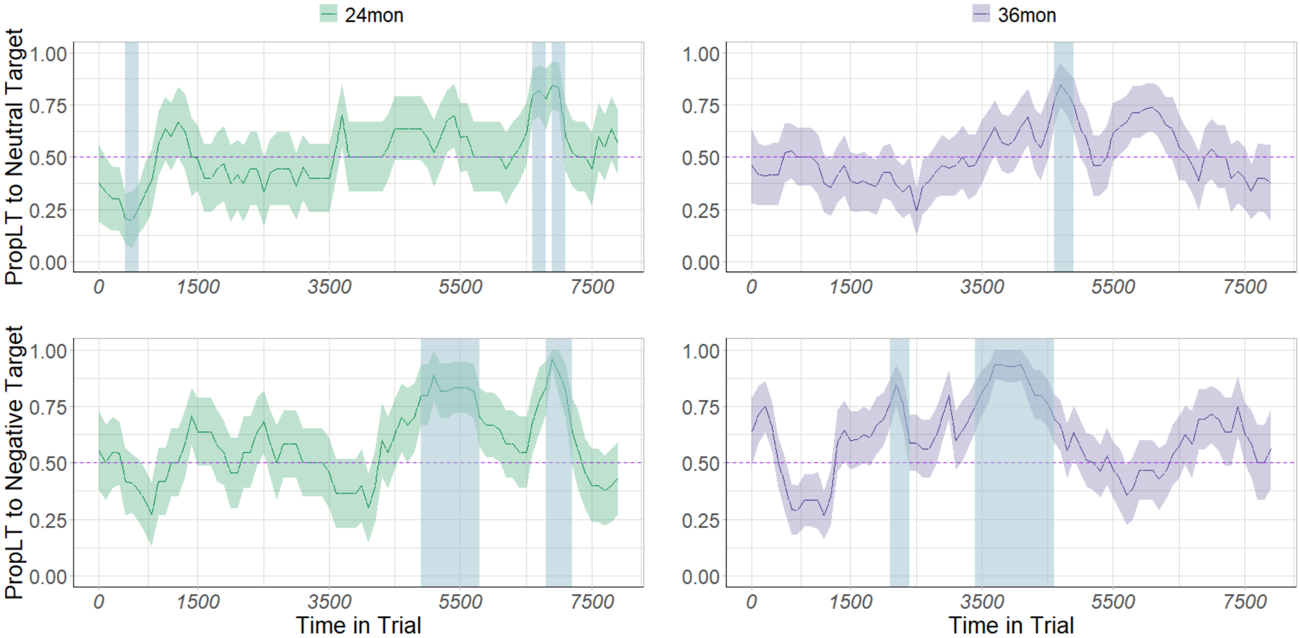
right: *M* = 0.03, *SD* = 0.08 ; *t* (2.44) = 8.38, *p* = .007, *d* = 8.60). Thus, the significant pre-label looking of 24-month-olds could be due to the position of objects.

For the 36-month-old toddlers, in the *neutral-positive* pair, the pre-label proportion looking was not different between left and right position (left: *M* = 0.64, *SD* = 0.37, right: *M* = 0.49; *SD* = 0.45), *t* (2.66) = 0.55, *p* = .63, *d* = 0.43, BF_{01} = 1.80). In *negative-positive* pair, the pre-label proportion looking was not different between left and right position (left: *M* = 0.29, *SD* = 0.20, right: *M* = 0.18; *SD* = 0.27, *t* (9.77) = 0.99, *p* = .34, *d* = 0.47, BF_{01} = 1.80). Thus, the significant pre-label looking of 36-month-old toddlers was not due to the position of objects. The following results reported toddlers' dynamic looking on the entire time course of label trials in terms of age groups.

24-month-olds. Regarding target looking, in *neutral-negative* pair, the 24-month-olds looked to neutral targets after the third label onset (6600 – 6800 ms, 66.75%; 6900 – 7100 ms, 60.80%), and to negative target after the second label onset (4900 – 5800 ms, 6.30%; 6800 – 7200 ms, 9.10%). In *negative-positive* pair, they looked to both positive and negative target after the second label onset (positive: 5000 – 5700 ms; 7.50%; negative: 4600 – 5300 ms, 19.05%; 5800 – 6200 ms, 30.40%; 6300 – 6700 ms, 28.50%; and 7000 – 7600 ms, 34.05%). Regarding distractor looking, in *neutral-positive* pair, they looked to positive distractor around the first label onset (1300 – 1500 ms; 68.05%); in *negative-positive* pair, they looked to positive and negative distractors around the first label onset (positive: 5000 – 5700 ms, 7.50%; negative: 1500 – 1900 ms, 22.05%).

Figure 4.4

Label Trials: *Proportion Target Looking in the Neutral-Negative Pair*

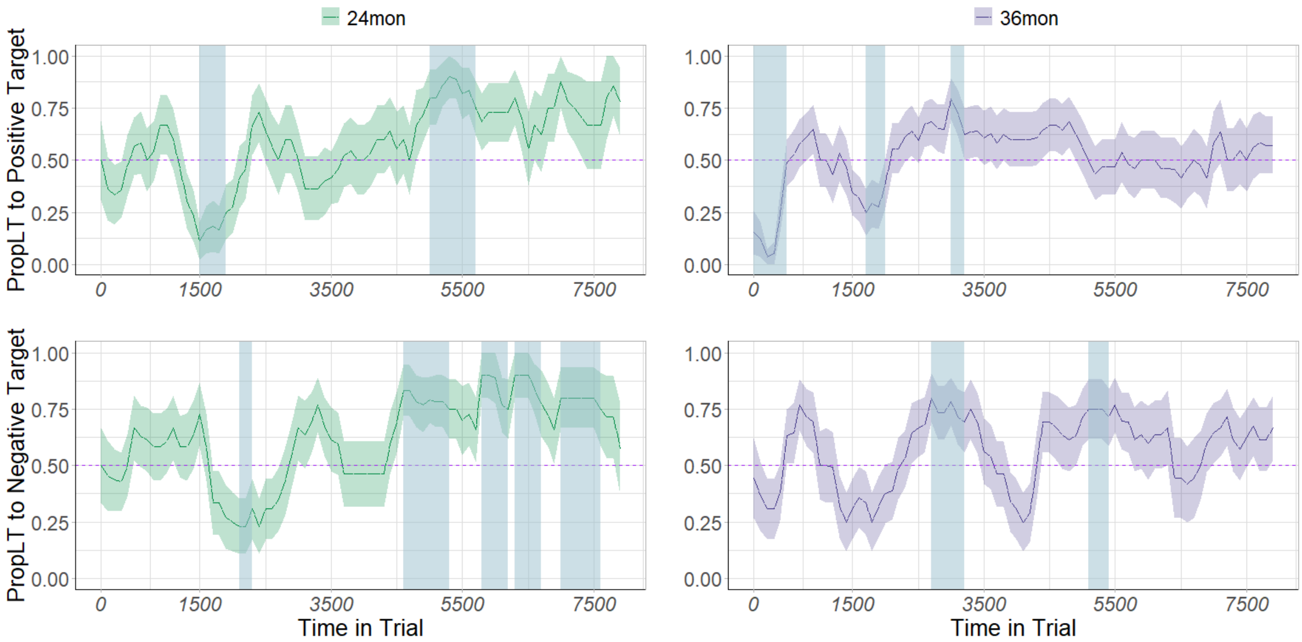


Note. The dashed line represents chance (0.50). The light blue shadow represents the time bins during which proportion target looking time is different from the chance (*p* < .05). The label onsets were at 1500 ms, 3500 ms and 5500 ms respectively.

36-month-olds. Regarding target looking, in *neutral-positive* pair, the 36-month-old toddlers looked to neutral target after the third label onset (6100 – 6500 ms, 23.45%; 6600 – 6900 ms, 39.85%; 7400 – 8000 ms, 34.70%). In *neutral-negative* pair, they looked to the neutral targets after the second label onset (4600 – 4900 ms; 35.60%), and to the negative targets after the first label onset (2100 – 2400 ms; 30.90% and 3400 – 4600 ms; 0.10%). In *negative-positive* pair, they looked to the positive and negative targets after the first label onset (positive: 3000 – 3300 ms, 62.60%; negative: 2700 – 3200 ms, 36.90%; 5100 – 5400 ms, 72.50%). Regarding distractor looking, in *neutral-positive* pair, they looked to the neutral distractor shortly after the first label onset (1900 – 2200 ms, 23.30%) and to positive distractor before label onset (500 – 600 ms, 84.05%). In *negative-positive* pairs, they looked to negative distractor before and after the first label onset (0 – 500 ms, 2.50%; 1700 – 2000 ms, 80.85%).

Figure 4.5

Label Trials: *Proportion Target Looking in the Negative-Positive Pair*



Note. The dashed line represents chance (0.50). The light blue shadow represents the time bins during which proportion target looking time is different from the chance (*p* < .05). The label onsets were at 1500 ms, 3500 ms and 5500 ms respectively.

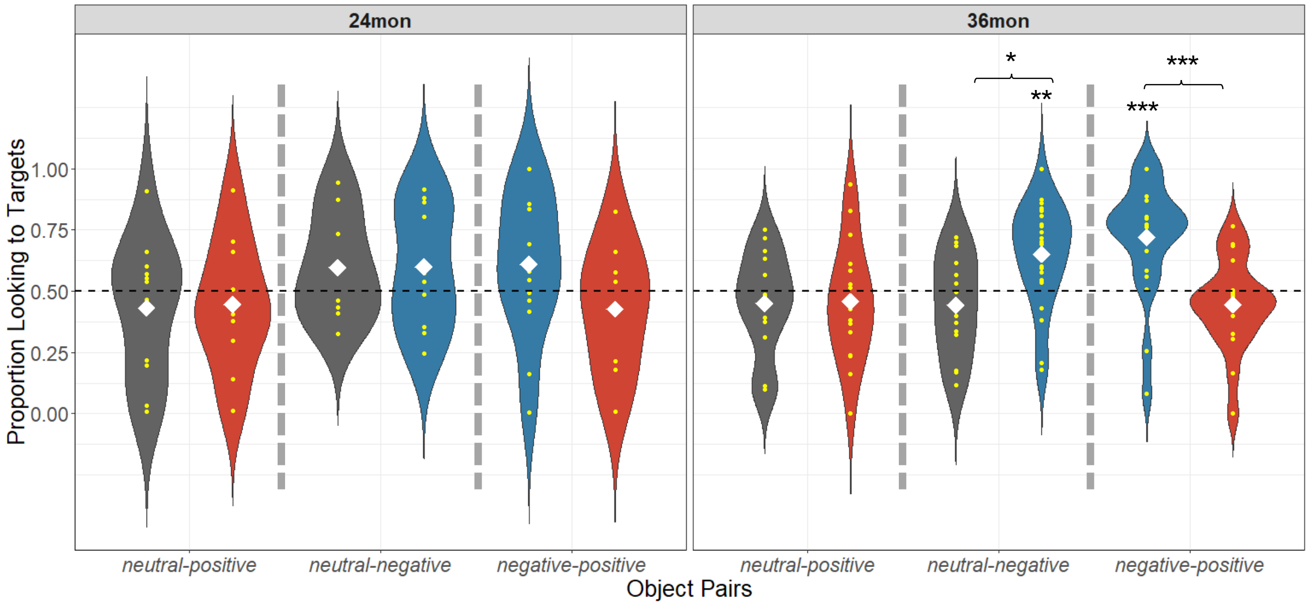
Overall, on label trials, regarding the pre-label looking, for *neutral-positive* pair, 36-month-olds looked to positive objects. For the *negative-positive* pair, 36-month-olds looked to the negative object before the first label onset. Regarding the looking after label onsets, apart from in the *neutral-positive* pair in which 24-month-olds did not look to either targets and 36-month-olds did not look to positive targets, both age groups showed above chance to target looking after hearing the corresponding labels, indicating that toddlers of both age groups processed the targets after hearing the corresponding labels. Meanwhile, the 36-month-olds oriented to the target earlier than the 24-month-olds, suggesting the older toddlers reacted to the labels faster than the younger ones did.

4.3.2.3 No-label Trials: Overall Proportion Target Looking

24-month-olds. As shown in Figure 4.6, for all object pairs, the 24-month-olds' proportion target looking after hearing affective cues was at chance (for the *neutral-positive* pairs: neutral target, M = 0.43, SD = 0.28, t (10) = -0.80, p =.44, d = -0.24, BF_{01} = 2.57; positive target, M = 0.44, SD = 0 .27, t (9) = -0.65, p = .53, d = -0.21, BF_{01} = 2.71; for *neutral-negative* pairs: neutral targets, M = 0.60, SD = 0.21, t (8) = 1.35, p = .21, d = 0.45, BF_{01} = 1.54; negative targets, M = 0.60, SD = 0.25, t (9) = 1.25, p = .24, d = 0.40, BF_{01} = 1.74; for the *negative-positive* pairs: negative targets, M = 0.61, SD = 0.29, t (13) = 1.39, p = .19, d = 0.37, BF_{01} = 2.57; positive target, M = 0.43, SD = 0.26, t (8) = -0.85, p = .42, d = -0.21, BF_{01} = 2.32). The 24-month-olds showed no differences in proportion target looking between the different affects across the object pairs, revealed by a LMEM with an interaction of affect and object pairs and random intercepts for items and participants ($\chi^2(5)$ = 6.99, p = .22, R^2_m = .10, R^2_c = .10, BF_{01} = 11107.96).

Figure 4.6

Proportion Looking Time to Targets in No-Label Trials for Two Age Groups



Note. White diamonds indicate the means of proportion target looking. The dashed line represents chance (0.50). $^{***}p < .001$; $^{**}p < .01$; $^{*}p < .05$.

36-month-olds. The 36-month-olds looked to negative targets at above chance level in the *neutral-negative* and *negative-positive* pairs but not to any other targets in each object pair (for the *neutral-positive* pairs, neutral target: $M = 0.45$, $SD = 0.21$, $t(15) = -0.95$, $p = .36$, $d = -0.23$, $BF_{01} = 2.66$; positive target: $M = 0.46$, $SD = 0.25$, $t(15) = -0.68$, $p = .50$, $d = -0.17$, $BF_{01} = 3.19$; for the *neutral-negative* pairs, neutral target: $M = 0.45$, $SD = 0.22$, $t(13) = -1.03$, $p = .32$, $d = 0.23$, $BF_{01} = 2.36$; negative target: $M = 0.65$, $SD = 0.21$, $t(21) = 3.38$, $p = .003$, $d = 3.10$; for the *negative-positive* pairs, positive target: $M = 0.45$, $SD = 0.19$, $t(17) = -1.23$, $p = .24$, $d = -0.29$, $BF_{01} = 2.14$; negative target: $M = 0.72$, $SD = 0.23$, $t(19) = 4.20$, $p < .001$, d

= 3.08). They looked to the negative targets longer than to neutral and positive targets in the *neutral-negative* and *negative-positive* pairs respectively, revealed by a LMEM ($\chi^2(1)$ = 10.04, p = .002) with an interaction of affect and object pairs and random intercepts for items, participants, and affect ($\chi^2(5)$ = 32.68, p < .001, R^2_m = .24, R^2_c = .24). Planned Tukey's HSD test indicated that proportion looking to negative targets was higher than that to the neutral target in the *neutral-negative* pair (β = 0.21, SE = 0.07, z = 2.89, p = .04), and to the positive target in the *negative-positive* pair (β = 0.27, SE = 0.07, z = 4.01, p < .001).

Comparison Between Age Groups. No difference in proportion of target looking was found between two age groups in terms of affect and object pairs. A LMEM with an interaction of age group, affect and object pairs and random intercepts for items and participants indicated a significant interaction ($\chi^2(11)$ = 36.90, p < .001, R^2_m = .18, R^2_c = .18). However, a planned Tukey's HSD revealed no differences in proportion target looking between age groups in terms of the affect cross the object pairs (all p > .91).

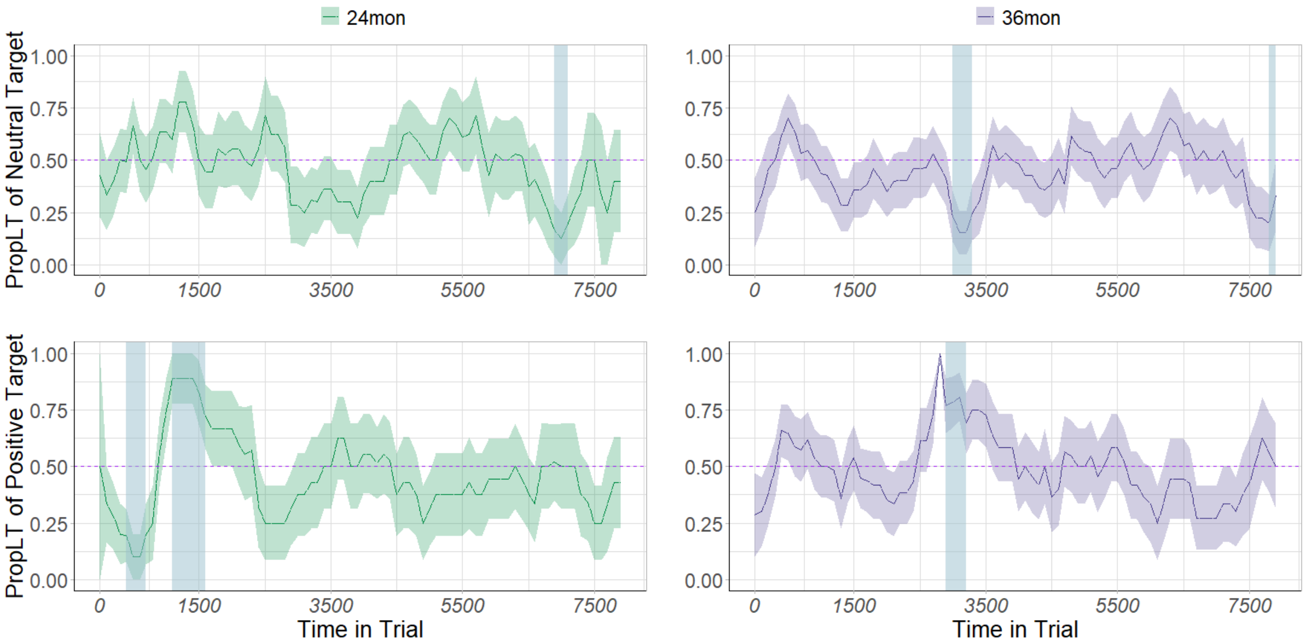
Overall, apart from the 36-month-olds demonstrating above chance overall proportion looking to negative targets, toddlers of both age groups showed no preference for any targets after hearing the corresponding cues.

4.3.2.4 No-label Trials: Time Series Analyses of Proportion Target Looking

The post-hoc independent *t*-test and time series analyses were conducted for each object pair for no-label trials. The affective cue onsets were at 1500ms, 3500ms and 5500ms respectively (neutral: *Look!;* positive: *Wow!;* negative: *Urgh!*) (Figure 4.7 – 4.9).

Figure 4.7

No-label Trials: *Proportion Target Looking in the Neutral-Positive Pair*



Note. The dashed line represents chance (0.50). The light blue shadow represents the time bins during which proportion target looking time is different from the chance ($p < .05$). The cue onsets were at 1500 ms, 3500 ms and 5500 ms respectively.

Examination of Position Bias. As with label trials, to verify the types of attentional bias during the pre-cue period, the post-hoc independent *t*-tests were employed to compare the proportion target looking at 200 – 700 ms of the time course in terms of left and right position for the trials in which toddlers' looking was significantly different from chance. The interval of 200 – 700 ms includes the period that indicates the significant results. For the 24-month-olds, in the *neutral-positive* pair, the significant pre-cue proportion looking time was not different between left and right position (left: $M = 0.30$, $SD = 0.33$, right: $M = 0.13$; $SD =$

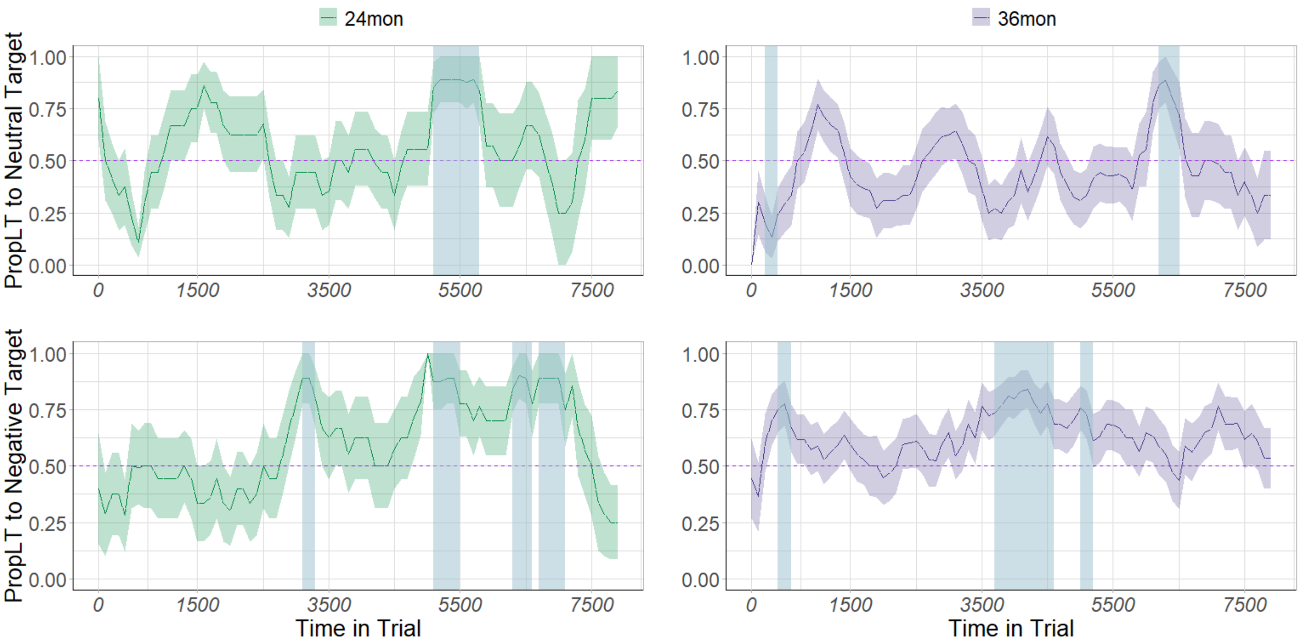
0.24, *t* (1.28) = 0.70, *p* = .59, *d* = 0.76, BF_{01} = 1.48). In the *negative-positive* pair, no difference of pre-cue proportion looking was found between left and right position (left: *M* = 0.20, *SD* = 0.39; right: *M* = 0.22, *SD* = 0.28; *t* (5.43) = -0.10, *p* = .92, *d* = -0.08).

For the 36-month-olds, for the *neutral-negative* pair, no difference of pre-cue proportion looking was found between left and right position in the trials that the neutral object was the target (left: *M* = 0.32, *SD* = 0.27; right: *M* = 0.16, *SD* = 0.23; *t* (5.32) = 1.04, *p* = .34, *d* = 0.73, BF_{01} = 1.44) or the negative object was the target (left: *M* = 0.73; *SD* = 0.34; right: *M* = 0.63; *SD* = 0.37; *t* (16.99) = 0.62, *p* = .54, *d* = 0.30, BF_{01} = 2.16). Thus, the pre-cue looking of toddlers in both age groups was not due to the position of the objects. The following results report toddlers' dynamic looking over the entire time course of no-label trials in terms of age groups.

24-month-olds. Regarding target looking, in *neutral-positive* pair, the 24-month-olds looked to positive target around the first label onset (1100 – 1600 ms, 21.25%). In *neutral-negative* pair, they looked to the neutral and negative targets after hearing the second and the first cue onset respectively (neutral: 5100 – 5800 ms, 3.65%; negative: 3100 – 3300 ms, 49.05%; 5100 – 5500 ms, 17.20%; 6300 – 6600 ms, 24.10% and 6700 – 7100 ms, 15.05%). In *negative-positive* pair, they looked to the positive and negative target after the second and the first cue onset respectively (positive: 5200 – 5500 ms, 47.65%; negative: 3200 – 3300 ms, 65.55%; 3400 – 3500 ms, 73.05%; and 7700 – 8000 ms, 37.35%). Regarding distractor looking, in *neutral-positive* pair, they looked to neutral (400 – 700 ms, 31.55%) and positive distractors (6900 – 7100 ms, 64.40%). In *negative-positive* pair, they looked to negative distractor (200 – 400 ms, 66.30%; 2100 – 2300 ms, 56.90%).

Figure 4.8

No-label Trials: *Proportion Target Looking in the Neutral-Negative Pair*

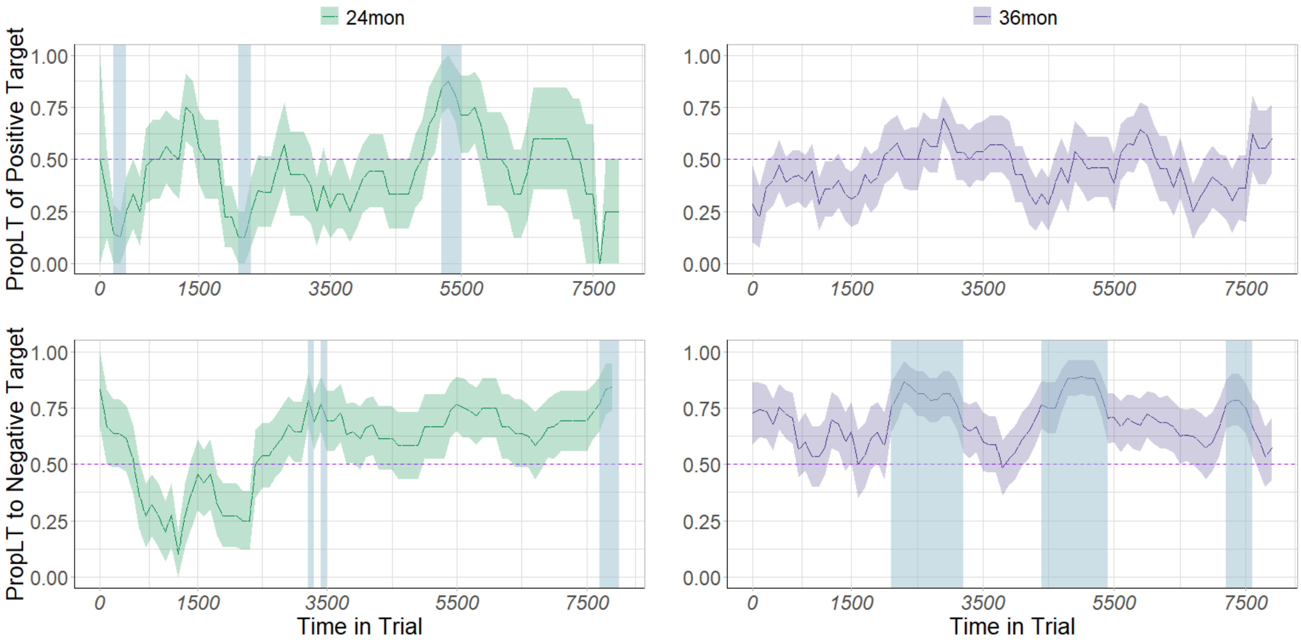


Note. The dashed line represents chance (0.50). The light blue shadow represents the time bins during which proportion target looking time is different from the chance ($p < .05$). The cue onsets were at 1500 ms, 3500 ms and 5500 ms respectively.

36-month-olds. Regarding target looking, in *neutral-positive* pair, the 36-month-olds looked to the positive target after the first cue onset (2900 – 3200 ms, 44.70%). In *neutral-negative* pair, they looked to the neutral and negative target after the third and second cue onsets respectively (neutral: 6200 – 6500 ms, 38.30%; negative: 400 – 600 ms, 49.45%; 3700 – 4600 ms, 2.90%; 5000 – 5200 ms, 52.70%). In *negative-positive* pair, they looked to the negative target after the first label onset (2100 – 3200 ms, 1.50%; 4400 – 5400 ms, 0.75%; 7200 – 7600 ms, 25.75%). Regarding distractor looking, in *neutral-positive*, they looked to the positive distractor after the first label onset (3000 – 3300 ms, 37.80%). In *neutral-negative* pairs, they looked to negative distractors before the first label onset (200 – 400 ms, 54.50%).

Figure 4.9

No-label Trials: *Proportion Target Looking in the Negative-Positive Pair*



Note. The dashed line represents chance (0.50). The light blue shadow represents the time bins during which proportion target looking time is different from the chance ($p < .05$). The cue onsets were at 1500 ms, 3500 ms and 5500 ms respectively.

Overall, the results indicated that, although toddlers of both age groups looked to three targets after the onsets of corresponding affective cues, they only reliably looked to negative targets in both *neutral-negative* and *negative-positive* pairs, indicating they associated negative affect with the corresponding objects.

4.4 Discussion

In this chapter, in addition to examination of the retention of label-object associations, we further investigated toddlers' retention of emotion-object associations and explored the development of top-down control of their looking during the recognition in 24- and 36-month-old toddlers. Without the pointing as robust reference of retention, the visual attention of toddlers in the current experiment reflects a complex interaction of the perceived cues and toddlers' developing attentional control. But we found evidence that, regarding the word learning, the 36-month-olds retained all the label-object associations, and the 24-month-olds retained the negatively label-object associations; regarding the retention of emotion-object association, both age groups associated only negative affect with the corresponding object. In the discussion, we discuss our findings in terms of the possible impact of the perceived emotions, the objects with emotionality and the labels and affective cues received by toddlers on their attentional processing during the referent selection learning phase and retention testing phase as well as the developmental change of the top-down control of supressing the impact of negativity bias on visual attention within the third year of life.

Regarding the impact of perceived emotions on the referent selection phase, in line with the findings of the experiments reported in the previous chapters, the negative facial expressions attracted toddlers' visual attention during learning, but this effect decreased with age: Although toddlers of both age groups looked to the negative face the most among three affective expressions, the 36-month-old toddlers spent less time looking at the face than the 24-month-olds did. Meanwhile, both age groups spent the similar amount of time processing the target object. These findings suggest that the 36-month-olds could better disengage their attention from others' emotionally negative expressions than the 24-month-olds during the learning of label-object associations. On one hand, after infants start to locomote, they increasingly refer to their caregivers' reaction when encountering novel objects and ambiguous situations, and receive more negative emotional expressions than before, such as anger, from their caregivers (e.g., Campos et al., 1992; Sorce et al., 1985). Thus, the older toddlers are more familiar with the emotionally negative faces than the younger ones. On the other hand, the older toddlers might be better at disengaging visual attention from the emotionally negative face than the younger ones because of the more mature frontal and parietal areas involved in attention processing (Giedd et al., 1999; Remer et al., 2017). Thus, although younger toddlers' visual attention was still grabbed by the negative expressions relative to the older ones, when learning the novel label-object associations under different emotional contexts, toddlers of both age groups can successfully map the novel labels to their referents.

Regarding the toddlers' retention of label-object and emotion-object associations, we assumed that the 36-month-olds would retain all the label-object associations and the 24-month-olds would retain negative label-object associations, and both age groups would retain the negative emotion-object associations. The results support these assumptions, but only when considering the time series analyses (i.e., the dynamics of target looking). In terms of overall proportion target looking, the 36-month-olds showed retention of negative label-object association only when the neutral object was the competitor. After hearing the affective cues, the 36-month-olds only identified the negative targets but not the neutral or positive targets. In contrast, the 24-month-old toddlers did not show above chance looking to any label- or emotion-object associations.

On the other hand, the time series analyses provided more informative looking patterns than the overall proportion target looking (e.g., Twomey et al., 2017; Wendt et al., 2014). Meanwhile, the above-chance proportion target looking in the time series analyses was also suggested being the evidence of retaining the new learned label-object associations (Twomey et al., 2017). But in the current study, the fixation on an object could be due to the effect of emotionality of objects, the labels or the affective cues toddlers heard or the outcome of competition between the objects with emotionality and the cues they heard. Thus, we defined the retention of associations was achieved only if the toddlers looked to the target in both testing trials which they were targeted, namely, toddlers looked to the positive targets in both *neutral-positive* and *negative-positive* pairs after hearing the corresponding labels or cues, we regarded that the toddlers retained the label-object or emotion-object associations unless their looking was interfered with the possible competition between target and distractor.

Thus, according to the time series analyses, in terms of word learning outcome, the 24-month-olds retained the negative label-object associations. Although they looked to neutral and positive targets in *neutral-negative* and *negative-positive* pairs, they might not have retained these label-object associations. Because, first, they failed to identify any targets in the *neutral-positive* pair; and second, their looking to neutral and positive targets when paired with a negative competitor could have been due to the mutual exclusivity after learning the negative label, that is, they knew that the heard label was not associated with the negative distractor, thus they switched their looking to another object, which was the target asked in that testing trial. Thus, the evidence found here only indicated the retention of negative label-object associations.

The possible reasons for the 24-month-old toddlers only retaining the negative label-object association in the current task could be an immature memory system failing to retain the neutral and positive information, and the visual-only and on-screen design of the task. On the one side, research on emotion-related memory has robustly shown that the information associated with negative affect is encoded more deeply and recognised more accurately compared to neutral counterparts (e.g., Kensinger & Corkin, 2003; Shafer & Dolcos, 2012). The 24-month-olds' retention might be facilitated by this enhanced effect of learning and memorisation caused by the perceived negative affect during learning. Additionally, neutrally and positively conditioned stimuli have been shown to evoke similar neural response which were less strong than those for negatively conditioned stimuli in both infants and adults (e.g., Hoehl & Striano, 2010a; Kuchinke et al., 2015). Thus, it is also possible that the ability of retaining neutral and positive information in memory is still limited in the 24-month-olds in the current case.

On the other side, however, studies conducted in the real-world using 3D objects reported that toddlers of the same age or even younger were able to recognise the newly learned label-object associations delivered in a general happy affect (e.g., Hilton & Westermann, 2017; Tomasello et al., 1996). The experimental setting might therefore be another influential factor. Furthermore, the evidence also showed that 24-month-old toddlers failed to learn a novel label-object association via video watching but succeeded when the association was taught by the experimenter physically presented (Troseth et al., 2018). Indeed, relative to learning via pre-recorded and 2D objects on the screen, learning novel label-object association with 3D objects in the real world provides a socially contingent environment and opportunities to familiarise with the objects, which convey more learning-relevant sensory inputs, facilitating the memory formation of new-learned label-object associations (e.g., Troseth et al., 2006; Roseberry et al., 2014; Fennell, 2012). Therefore, we suggest that the current on-screen, pre-recorded video learning is not sufficient for the 24-month-olds to also retain the neutrally and positively conditioned label-object associations.

For 36-month-old toddlers, based on the previous finding that toddlers at the same age robustly retain newly learned label-object associations after a challenging referent selection task (Axelsson & Horst, 2014), they should have retained all the label-object associations. But as revealed by the time series analyses, they retained negative and neutral label-object associations but failed to identify positive label-object associations when paired with a neutral competitor. This fact could be due to a competition for limited attentional resource between the positive target evoked by the label and the neutral competitor activated by the neutral tone (Mathews & Mackintosh, 1998; Yiend, 2010), because the identification of positive label-object association in the current study requires not only the generalisation of the label from positive to neutral affect, but also the sustaining looking to the target. In the time series analysis, we can see that, after hearing the label for the positive object, the 36-

month-olds switched their looking away from the neutral competitor, suggesting they responded to the labels, but their looking to the positive target did not reach an above chance level, indicating they were unable to sustain looking on the target.

The possible reasons for this fact could be that, on one hand, the neutral tone might be associated with the neutral competitor implicitly after learning in neutral labelling affect, affecting toddlers' attention distribution. On the other hand, unlike the negative object, the positive object may not salient enough to grab toddlers' attention towards it (Hoehl & Striano, 2010a), which may hinder the 36-month-old toddlers from identifying and sustaining looking to the positive target. Moreover, given that the older toddlers retained the neutral label-object association, when they heard a label that is not associated with neutral object, they should have oriented looking to positive target. But the 36-month-olds' looking was at chance on the time course after hearing the labels of positive targets, reflecting, again, they were unable to sustain looking on the positive target. Thus, we suggest that the ability of sustaining selective attention is not fully developed at the age of 36-month. Taken together, the 24-month-olds' learning of novel label-object associations is facilitated by the perceived negative affect during the learning; although the 36-month-olds retained all the label-object associations, their top-down control of sustaining visual attention to targets is still developing.

Regarding the retention of emotion-object associations, we assumed that both age groups should retain negative emotion-object association because of the enhancement of negative objects in terms of attention (e.g., Carretié et al., 2001). The results of time series analyses confirmed this assumption. After hearing the negative cues, both age groups looked to negative targets and sustained their looking to them regardless of the emotionality of competitor. In terms of retaining the neutral or positive emotion-object associations, we did not find systematic looking in both age groups after the affective cue onsets. In the current no-label trials, the affective cues used were to test whether toddlers can identify the objects associated with the particular affect. Specifically, there should be two cognitive process involved in the learning if toddlers successfully identify the corresponding objects after hearing the cues in the testing. One is that toddlers attribute the affect to the objects during learning; the other is that toddlers associate the cues (*Look! Wow! Urgh!*) with the objects. That is, it is possible that the emotionality is attached to the object after learning novel objects in the emotional contexts, but this emotionality of objects cannot be detected by the measurement of preferential looking in the case of neutral and positive affect.

Referring to previous findings, an above-mentioned ERP study with 3-month-olds found that positively conditioned objects affected attention similarly to neutrally conditioned objects (Hoehl & Striano, 2010a), and related findings in adults indicated that seeing newly learned positive written pseudowords evoked a similar ERP component as a neutral counterpart, indicating a similar attentional processing of neutral and positive stimuli (Kuchinke et al., 2015). Thus, toddlers might not particularly associated neutral and positive affect with novel objects. Taken together, we suggest that, first, perhaps looking time is not a reliable indicator of having learned the emotion-object associations; second, the objects learned in neutral and positive conditions did not affect toddlers' visual attention in the testing phase like the negatively trained object did.

Regarding the developmental change of top-down control in the third year of life, in line with the finding that, in children aged from 12 to 36 months, their speed of target identification becomes faster in a visual search task as they grow (Gerhardstein & Rovee-Collier, 2002), we found that the 36-month-olds oriented to the targets faster than the 24-month-olds did. Moreover, compared with the younger toddlers, the older toddlers were more likely to sustain looking to the targets asked by labelling. Likewise, the older toddlers, but not the younger toddlers, sustained their looking to the negative targets at above chance levels in the no-label test trials. Although older toddlers' looking patterns could have benefitted from a negativity bias (e.g., Carver & Vaccaro, 2007) and no generalisation was required at test, their top-down control, which allowed older children to sustain looking to the target while avoiding looking to the negative distractor, is nonetheless more developed than the 24-month-old toddlers.

Overall, Chapter 4 examined the effect of perceived emotions on word learning in the 24-month-olds and the 36-month-olds and explored the possible developmental change of top-down attentional control within the third year of life. In terms of word learning outcome, taking both overall looking and time bin analyses into account, the 36-month-old toddlers retained all the label-object associations, and the 24-month-old only retained negative label-object associations, suggesting the negative affect facilitates younger toddlers' learning of novel label-object associations. In contrast, for the retention of emotion-object associations, both age groups only associated negative cues with corresponding objects. Meanwhile, the top-down control of attention, which allows toddlers to disengage looking from salient distractors and sustain looking to targets, develops over this age period but is not fully developed by 36 months. In sum, as the toddlers develop, the retrieval of novel label-object associations gradually becomes less affected by the newly learned objects' emotionality. The top-down attentional control is more developed in the 36-month-olds than in the 24-month-olds.

Chapter 5: General Discussion

In early life, children learn words in the social interaction consisting of emotional and linguistic information (Clark, 2016; Tomasello, 2003). During the learning of label-object associations in the context mixed with objects, linguistic, emotional information, children need to process the emotional and linguistic information they perceive and integrate the relevant cues, such as associating labels and perceived emotions with the objects, to achieve the learning of label-object associations. With the background that others' emotional expressions affect individuals' attention allocation and memory during learning (e.g., Dolan & Vuilleumier, 2003; Kensinger, 2004; Yiend, 2010) and the young word learners integrate multiple cues, such as the linguistic and affective cues, into the learning of novel label-object associations (Hollich et al., 2000), the current work investigated the impact of perceived emotions on word learning in toddlers and adults using a referent selection and retention paradigm via eye tracking. Specifically, we asked whether the emotional cues participants perceived during the learning phase influence word learning outcomes, indicated by retaining the label object associations, and whether individuals also integrate the perceived emotional cues into the learning of novel objects, indicated by retaining the emotion-object associations.

5.1 Main Findings and Implications

Chapter 2 first examined whether the perceived emotions influence word learning and retention in adults and 30-month-old toddlers. Based on the findings in Chapter 2, Chapter 3 further explored the effect of emotionally salient distractors on 30-month-old toddlers' looking to and retention of label-object associations and the effect of objects with negative emotionality on visual attention. Chapter 4 then studied the retention of label-object and emotion-object associations and the development of top-down attentional control of restraining looking to the negative distractor and sustaining looking on the targets in 24- and 36-month-old toddlers.

Our results reveal complex relations between the perceived emotions and visual attention in participants during the learning and recognition of the novel label-object associations in different emotional contexts. During learning, all the participants looked at negative expressions, but they looked at the novel target objects equally across the emotions, suggesting that others' emotional expressions did not affect their visual processing of novel objects. Regarding the word learning outcome, the older age groups (30-, 36-month-olds and adults) showed evidence of retaining all three new-learned label-object associations across experiments, while 24-month-olds retained only the negative label-object association. Regarding the retention of emotion-object associations, toddlers only associated negative cues with the corresponding objects, but adults retained all the emotion-object associations. In the current chapter, I will discuss the findings in terms of the impact of perceived emotions on visual attention in the referent selection learning part and the impact of perceived linguistic and emotional cues as well as the objects with newly learned emotionality in the retention testing part. Additionally, the possible impact of experimental factors, such as testing time, the measurements of looking and pointing on performance on the retention, would also be discussed.

5.2 The Impact of Perceived Emotion on Referent Selection

In the real world, young word learners acquire novel label-object associations in social interaction with others, which are awash with emotional information that affects infants' perception and attention (Clark, 2016; Tomasello, 2003). The current learning phase included neutral, positive and negative expressions to mimic the situations that young word learners might encounter in the real world. Thus, to what extant the perceived emotional expressions affected the word learners to process the referents of the novel labels could be revealed. In the following section, how the participants allocated visual attention when processing the perceived emotional expressions and the novel targets would be discussed.

5.2.1 The Impact of Perceived Emotional Expressions on Visual Attention

In line with studies reporting that negative expressions capture more attention relative to neutral or positive expressions (e.g., Eastwood et al., 2003; Peltola et al., 2008), both toddlers and adults spent more time looking at negative than neutral and positive facial expressions with the exception that adults' looking time to negative and positive expressions was similar. In the current work, the positive and negative emotional expressions were presented in a more playful, exaggerated manner in terms of prosody and body movements relative to the neutral expressions (as described in Chapter 2). Thus, both positive and negative emotional expressions should be more attention grabbing compared to the neutral expression presented in the learning task because they included more movements and more variable sound patterns (e.g., Nelson & Mondloch, 2018; Rigoulot & Pell, 2012). This is the case in the adults; however, only negative expressions attracted toddlers' visual attention more than the neutral one, not positive expressions. This fact might be due to toddlers having had less experience of others' negative expressions in daily life compared to positive emotion, making the negative expression more novel than the positive one (Lieberman, 2017). However, when comparing the face looking cross the age groups, we found that adults spent less time looking to the facial expressions than the toddlers generally and the 36-month-olds' face looking is less than the 24-month-olds' among toddlers, suggesting that, with an increasing learning experience and maturation of learning ability, when word learning happening in the situation containing the perceived emotions and the objects being learned, the perceived emotions become less attractive with respect to visual attention as individuals develop.

5.2.2 Looking to the Novel Targets

In terms of the looking to the novel objects being learned in the different emotional context, the visual attention distribution follows a U-shaped profile across ages, with 24- and 36-month-olds and adults looking to the target longer than 30-month-olds[1]. The finding could be due to an interaction between a decreasing novelty preference with developing control of maintaining looking on the targets and the proficiency of word learning. First, the fact that 24-month-old toddlers sustained their visual attention to the novel objects longer than 30-month-olds but similar to the older age groups might be due to the novelty bias towards previously unseen object among the known ones in the younger group (e.g., Kucker et al.,

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[1] To investigate the impact of perceived emotions on participants' visual attention during learning, we submitted the proportion target looking in referent selection trials to a LMEM with an interaction of age groups (24-, 30-, 36-month-old and adults) and affect (neutral. positive and negative), and random effects of by-item and by-participants intercepts. the result reveals a significant interaction, $\chi^2(11) = 140.76$, $p < .001$, $R^2_m = .36$, $R^2_c = .78$. But only the 30-month-olds was found looking to target less than all the other age groups ($p < .001$).

2018). While at the age of 30 months, the effect of the novelty bias on visual attention was not as dominant as that at the 24-month-olds.

Second, compared to the adults and the 36-month-olds, the 30-month-olds might have needed to spend more time processing the stimuli, because their less looking to the targets indicates they spent more time processing the known competitors co-presented with the novel targets. On the one hand, through development children become more proficient in learning label-object associations in social context because they are more familiar with the language they hear and the social cues they see, such as emotional expressions and social gaze (Hollich et al., 2000). Hollich and colleagues (2000) examined the learning of novel label-object associations in 12- , 19- and 24-month-old toddlers. The experimenter first presented toddlers with a boring (one colour) and an interesting novel objects (multicoloured) and trained them by labelling and looking at either boring or interesting objects. The authors found that, during learning, the 12- and 19-month-olds looked more at the interesting than the boring object no matter which object the experimenter looked at; but the 24-month-olds looked to the target objects irrespective of whether they were boring or interesting. The older children therefore were able to weigh these intrinsic and social cues more proficiently to identify the referents of labels than the younger ones. Thus, it is no surprise that the 36-month-olds and adults allocated more visual attention on the targets.

On the other hand, it is also possible that the 30-month-olds' ability of sustaining visual attention on the novel targets and ignoring the co-presenting known competitors was not as developed as it was in the 36-month-olds and in adults with the consideration of the maturation of frontal and parietal areas, which is suggested being responsible for mediating this ability of top-down control with respect of visual processing (Giedd et al., 1999; Horst et al., 2010; Kastner & Ungerleider, 2001). Overall, when learning the novel label-object associations in the different emotional context, individuals' visual attention is attracted by the others' negative affect relative to the neutral and positive affect, but their ability to select the referent of the labels is not affected by the perceived emotions during learning. Furthermore, as individuals grows, becoming more experienced in learning words and evaluating the perceived emotional and language cues, their visual attention was affected less and less by the perceived negative emotions and allocated more and more on the referents.

5.3 The Impact of Perceived Emotions on Retention

After learning the novel label-object associations in different emotional contexts, participants have encoded the labels and emotionality associated with objects in their memory. In the retention phases, to examine whether toddlers integrate the linguistic and emotional cues into word learning, that is, retaining the label-object and emotion-object associations, the following indices were used in the current word: 1. above-chance overall proportion target looking (Chapter 2, 3 & 4); 2. above-chance pointing to target (Chapter 2 & 3); and 3. above-chance proportion target looking in the time series analyses (Chapter 4). Thus, to demonstrate the successful retention, the participants were required to detect objects presented in each test trial, orient their visual attention to the target object after hearing the labels or cues, then sustain attention to the target or point to it. Based on the current findings, participants' performance of recognising label-object and emotion-object associations was affected by the objects they saw, the linguistic and affective cues they heard and even maybe the measurements employed to examine the retention. Thus, in this section, I will first discuss the effect of negativity bias on participants' visual attention, second, the effect of labels and affective cues on participants' learning outcome; third, the performance of recognition when perceiving the labels and affective cues from the perspectives of the bottom-up and top-down attentional processing; in the end, I will also discuss the reliability of looking and pointing as indices of retention in the current work.

5.3.1 The Effect of a Negativity Bias on Attention

Previous research demonstrates that negatively conditioned objects capture more attention relative to positive or neutral counterparts in young children on the neural level (e.g., Carver & Vaccaro, 2007; Hoehl et al., 2008). The current work provides evidence that the negatively conditioned objects also capture visual attention in toddlerhood. On the one hand, considering the evolutionary importance of disgust, the negative affect employed in the current experiments, which might indicate a potential poisonous, contaminated substance (Curtis et al., 2011), enhanced the processing of the corresponding novel objects. Especially for young children, who refer to adults' response when they encountered novel objects (e.g., Moses et al., 2001; Sorce et al., 1985), might therefore focus more on objects to which others have expressed disgust.

On the other hand, however, this object might have induced a "negativity bias" on attention because of the toddlers' understanding of the perceived emotions. Empirical evidence has shown that, after observing adults showing negative and positive emotions towards novel objects, infants as young as 12-months regulated their behaviours by avoiding playing and approaching the negatively conditioned objects but not the neutrally and positively conditioned ones (e.g., Carver & Vaccaro, 2007; Mumme, & Fernald, 2003), indicating that they might understand some implications of negative emotions, such as danger. Meanwhile, the toddlers have had more experiences with novel toys in daily life as they grow (e.g., Campos et al., 1992; Hoehl & Striano, 2010b) and they may have experienced surprise when seeing the actress looking at the novel objects, which were not ‘perceptually dangerous’ such as spider or snakes, in an emotionally negative manner (Hoehl et al., 2017). As a result, the negative object stood out from the three novel objects.

Furthermore, compared with viewing neutral and positive facial expressions, the neural connections between emotional face perception areas (e.g., amygdala, inferior occipital gyrus) and somatosensory cortex (Brodmann’s area 2) are only activated when viewing disgusted facial expression (Tettamanti et al., 2012). Similarly, studies measuring physiological responses towards others’ static or dynamic neutral, happy and disgusted expressions revealed an increased skin conductance, facial electromyogram, and more negative facial expressions when viewing disgusted than neutral and happy expressions in both adults and infants (e.g., Mumme & Fernald, 2003; Schienle et al., 2001). Thus, it is possible that in our study, the actress’ emotionally negative reaction (disgust) towards the novel object might have made this negative-associated object more salient relative to the neutral and positive ones during the learning process, with a resulting effect of enhanced attention towards the negative object during recognition in the test phase. Nevertheless, apart from the impact of negative objects on attention, toddlers' performance of recognition was also affected by the labels and affective cues they perceived during the retention test phases.

5.3.2 The Effect of Perceived Labels vs Affective Cues on Recognition

The labels and affective cues referred to different features of the newly learned objects: labels are referential information and affective cues refer to objects' emotionality. As mentioned at the beginning of this chapter, if toddlers integrate the linguistic and affective cues into the learning of label-object associations, they will retain the associations between not only the label and objects but also the affect and objects. In the current work, the toddlers used the perceived linguistic and affective cues to acquire the features of objects (Monaghan et al., 2018): the sentence structure used in referent selection to train toddlers specified *bosa, teebu, coodle* as names of novel objects and attributed emotionality to the novel objects via affective expressions (e.g., *Wow! Look! This is a bosa!*). After the learning phase, the retention results of looking and pointing indicate that toddlers integrate labels but might only integrate negative affect into the representations of the novel objects.

Infants as young as 12 months privilege words over other sounds in the learning of objects (Althaus & Westermann, 2016; MacKenzie et al., 2011), and so did the toddlers in the current work: they associated labels with the objects more readily than the affective cues. In particular, toddlers understood the grammatical structure of linguistic cues and mapped *bosa* to the novel object after hearing *this is a bosa!* in the referent selection learning phase (Hollich et al., 2000). Similarly, 13- and 18-month-olds associated both words and non-linguistic sounds with objects when they were instructed *Look at what you have!*

[word/sound] That is what we call that one! (Campbell and Namy, 2003). In contrast, the affective cues used in the current study (*look, wow, urgh*) were attributed to the novel objects via the actress' expressions in the referent selection phase (e.g., *Urgh! Look! This is bosa!*) instead of labelling the objects *wow* or *urgh* directly. Thus, labels serve as better referential cues relative to affective cues in terms of recognising an object as the target in the retention test phase.

Regarding the recognition of emotion-object associations in the testing trials presenting only the affective cues, adults retained all the associations, but toddlers in all age groups attended more to the negative objects than to the neutral and positive ones after hearing the corresponding cues. The findings reflect two possibilities: one is that toddlers only associated negative affect but did not specifically associate neutral and positive affect with the novel objects; the other is that the toddlers retained the neutral and positive emotion-label associations but failed to recognise them during testing. Regarding the former possibility, as had been discussed above, the neutral and positive affect perceived during learning might not be as important as negative disgust affect with regard to the evolutionary function (Curtis et al., 2011). Meanwhile, as toddlers grow, they refer to adults' emotional expressions to disambiguate the features of novel objects, then pay more attention to the novel objects conditioned with adults' negative expressions (e.g., Carver & Vaccaro, 2007; Moses et al., 2001; Mumme, & Fernald, 2003). As a result, the objects associated with the negative affect captured more attention, were learned more robustly than their neutral and positive counterparts and became the one to be memorised and recognised.

However, considering the findings showed that adults retained three newly learned emotion-object associations and that toddlers retained the positive label-object associations but failed to recognise the association when the salient negative distractor was presented at the same time, it is also possible that toddlers retained the neutral and positive emotion-object associations but failed to recognise them during testing. In this case, first, unlike the labels, the affective cues (*look, wow, urgh*) were not directly linked with the objects. Although the negativity bias facilitated toddlers to identify the negative targets and the negative cues might exaggerate the effect, the perceived neutral and positive cues and the corresponding objects were not influential enough in terms of grabbing attention (e.g., Hoehl et al., 2008; Rodrigues et al., 2009). Second, unlike the adults, the mature learners with a developed attention control, toddlers' top-down control of attention is immature; specifically, considering the development of frontal and parietal areas, mediating the attention control, the ability of supressing and disengaging attention from the distractors and maintaining attention on the targets is still developing within the third year of life (Giedd et al., 1999; Remer et al., 2017), leading to toddlers' failure of recognising the neutral and positive emotion-object associations.

Therefore, a competition for attention might happen between the target and salient distractors in toddlerhood, that is, if the targets grabbed more attention, toddlers would recognise the target; if the distractors grabbed more attention, toddlers would identify the distractors as the trial target; if the target and distractors grabbed similar amount of attention, toddlers might fail to identify any objects. The following part will discuss participants' recognition in the current task from the perspectives of the bottom-up processing, activated by the perceived objects and cues, and top-down processing, the ability of restraining or disengaging attention from the negative object and sustaining attention on the targets.

5.3.2.1 Attentional Processing in Retention Task

The bias competition theories of attention proposed that the sensory inputs compete for attention via bottom-up sensory-driven mechanisms and top-down influences (Kastner & Ungerleider, 2001; Yiend, 2010). In the current retention task, seeing the novel objects and hearing the auditory stimuli (labels, affective cues) activated bottom-up attentional processes, while identifying the referents of the heard labels and affective cues constituted a top-down attentional process. As described above, the retention performance of toddlers was affected by the negatively conditioned objects, in this case, although all the novel objects activated the bottom-up processing, but only the negative object evoked an attentional bias towards it. Thus, to demonstrate successful retention as measured, it is necessary to have a well-developed top-down attentional control to select the targets, suppress or disengage attention from the salient negative distractor and sustain visual attention on or pointing to the targets.

In this case, relative to toddlers, adults demonstrated a mature top-down attentional control in terms of target recognition. As reported in Chapter 2, adults' target looking and pointing were above chance for all three newly learned label-object associations, indicating that their recognition was not affected by the negative distractors. Considering the findings of other emotion conditioning word learning studies, adults' neural responses were enhanced when recognising the newly learned negative rather than the neutral and positive pseudowords

(Fritsch & Kuchinke, 2013; Kuchinke et al., 2015), the effect of negativity bias on attention still exists in adulthood. Therefore, adults can supress the attentional bias evoked by the negative objects in the current study. Moreover, in terms of the emotion-object associations, adults associated positive and negative cues with their corresponding objects revealed by both above chance looking and pointing. Notably, they pointed to neutral objects after hearing neutral cues (*look*), but they did not look systematically to the neutrally trained object. The finding suggests that adults pointed to the neutral object ultimately might because they retained the objects associated with positive and negative cues and performed a mutual exclusivity when being asked to choose an object when hearing the neutral cues. Combined the evidence of adults' looking and pointing when recognising the label-object and emotion-object associations, they demonstrated a well-developed memory ability, stable control of visual attention, and were not affected by the negativity bias. In contrast, the toddlers' memory ability and top-down attentional control are still developing.

Their looking and pointing to the targets after hearing the labels and affective cues reflected the outcome of not only retention but also the competition for attention between salience of target and distractors. Generally, toddlers' attention was affected more by negative relative to neutral and positive emotionality in the currect work. The 24-month-old toddlers only retained the negatively trained label-object association but not neutral and positive associations. Specifically, after hearing the neutrally spoken label of a negative object, 24-month-olds sustained their looking to the target, indicating not only that did they generalise the negatively spoken label in learning to a neutral tone at test, but also that they successfully identified the referent of the label. The finding further confirms that learning novel knowledge when perceiving negative affect facilitates young word learners to memorise the novel knowledge (e.g., Kensinger & Corkin, 2003; Shafer & Dolcos, 2012).

Moreover, the 30-month-olds pointed and looked to negative objects when hearing neutral cues (*look*!), that is, they failed to look but managed to point to target neutral label-object associations when negative distractor was also presented is in line with the finding that attention is affected the most when the differences in emotional intensity of the stimulation is the greatest, such as the highly arousing negative and neutral comparison (Shafer et al., 2012). Even the oldest toddlers recruited in the study, the 36-month-olds were more likely to sustain their looking to the negative targets compared to positive and neutral targets in the passive looking task. Thus, the presence of negative object evoked a strong bottom-up processing, if it was targeted, it would promote toddlers to allocate attention on it; but if it was the distractor, it would interfere with toddlers' ability to direct their visual attention to the neutral target. However, this attentional bias towards the negative object declined as toddlers develop based on the evidence that the 30- and 36-month-olds retained all the label-object associations irrespective of the perceived emotions associated with the objects. The weakened advantage of negative affect on learning could be the results of, first, a more developed memory system in the older age groups compared with the 24-month-olds (Axelsson & Horst, 2014; Horst & Samuelson, 2008; Horst et al., 2010) and second, a more developed top-down control of disengaging attention from negative distractor and sustaining looking on the target in the older age groups.

Overall, participants processed the linguistic and affective cues as well as novel objects during word learning. The labels, as the linguistic cues, dominate the formation of label-object associations; but the affective expressions, as social pragmatic emotional cues, shape the emotionality of objects. The negative affect attracted more attention from both adults and toddlers relative to the neutral and positive expressions, but this impact of negative affect decreases as individuals grows. During testing, the 24-month-old toddlers' retention of label-object associations was promoted by the negative affect perceived during the learning process, but the word learning outcome of toddlers older than 30-month-old was not affected by the perceived emotions, indicating a development of learning and memory ability within the third year of life. Moreover, because the 36-month-old toddlers were still affected by the negativity bias, we suggest that the top-down control of supressing the impact of negative salient distractor is still developing at the end of the third year of life.

5.4 Looking and Pointing as Indices of Retention

The findings of 30-month-old toddlers' looking and pointing to negative objects in the no-label trials asking by neutral cues further confirmed the salience effect of negative objects on attention and memory and also revealed the methodological consideration in the current work. In addition to looking, pointing further reflects individuals' attention selection when recognising targets in the current work. For example, when visual attention is affected by salient negative distractors, toddlers did not look to the target referents after hearing the labels (Chapter 2 and 3) but pointing provides additional evidence of their retention of label-object associations. That is, looking as the implicit index of retention while pointing as the explicit index. Interestingly, toddlers looked for longer at targets when asked to point than when no pointing was required[2]. Specifically, 30-month-olds identified all the label-object associations in the design with looking and pointing in the retention phase (Chapter 3), but 36-month-olds' overall proportion target looking was above chance only for the negatively trained label-object association in the looking-only retention task (Chapter 4). Based on previous evidence indicating that 36-month-olds recognised all newly learned label-object associations in a touch screen word learning game (Axelsson & Horst, 2014), we suggest that 36-month-olds should also retain all the associations in the current case but they did not sustain their looking to neutral and positive targets label-object associations to above chance level because the length of sustained looking in the passive looking task is not as high as in the task requiring both looking and pointing.

Indeed, a recent study suggests that toddlers' looking responses alone are qualitatively different from the looking responses with pointing. Hagihara et al. (2021) created models to predict pointing responses based on the direction of children's preferential looking and evaluated the models based on videos in which 18- to 22-month-old toddlers' word comprehension was tested in a forced-choice pointing paradigm in a screen-based task. The authors tested the models' prediction accuracy by comparing pointing generated by the models based on face and gaze angle with previous manual coding of the videos. They found that the models predicted pointing direction more accurately when toddlers pointed clearly to

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[2] To test this assumption, we further employed a LMEM to examine whether toddlers' proportion target looking was greater when they knew they need to point to the target than when they did not (Chapter 3). The proportion target looking of the first label trials was compared with the rest label trials in the first label block in the RT1. Because toddlers did not know they needed to point in the first label trial. The result indicates toddlers' proportion target looking when not knowing pointing (*M* = 0.51; *SD* = 0.23) was less than when knowing pointing (*M* = 0.62; *SD* = 0.22), $\chi^2(1) = 5.90$, $p = .02$, $R^2_m = .06$, $R^2_c = .18$.

the object, but accuracy dropped when toddlers' pointing was unclear, indicating that the face/gaze angle, determining toddlers' preferential looking, was towards the object more clearly when toddlers pointed compared to when they did not point. Thus, in the current work, toddlers' looking was affected by emotionally negative objects in the test trials and thus became unclear as an index of retention, while toddlers' pointing provided a more reliable and explicit index of retention and may also have facilitated toddlers to prolong their target looking in the test trials.

5.5 Limitations & Future Direction

The current work revealed that only 24-month-old toddlers' word learning was affected by the emotions perceived during learning. Although we found that perceived negative emotions facilitate younger toddlers' retention of novel label-object associations, it remains unclear how this facilitation happens. Despite the activation of the amygdala-hippocampus circuit when processing the negative information promotes learning in adults (McGaugh, 2004; Murty et al., 2010), it remains unclear in early life. Thus, to further illustrate the mechanism of this facilitation, a more fine-tuned methodology, for example event-related potentials or functional near-infrared spectroscopy, could be employed. These brain imaging technologies can better reveal the detailed neural processing of young word learners during information encoding, maintenance, and retrieval when they acquire novel label-object associations in different emotional contexts.

Another limitation is that, in Chapter 4, we used both overall proportion target looking and time series analyses as the indexes of retention, but we did not collect pointing data.

Thus, whether toddlers in that study would have demonstrated retention by pointing is unknown. Taking into account the finding that toddlers' target looking was clearer when the task required looking and pointing and looking as the implicit index of retention while pointing as the explicit index, future work should explore the top-down control of visual attention with and without pointing, such as to include or exclude the requirement of pointing in a task, during early learning.

Additionally, the current work revealed that the labels and perceived emotional cues were integrated independently with respect to word learning. It is worthwhile to explore how the labels and affective cues was integrated into toddlers' learning of object. Research has reported that adults' neural reaction to negative emotional expressions reduced when mapping labels to facial expressions, such as the word *angry* and negative emotional expressions such as a frown or reddish facial expression, reflected by diminished response in the amygdala (Matthew et al., 2007). The authors suggest that labelling the affective facial expressions might help individuals to regulate negative affect. Relatedly, to explore the possible mechanisms of regulating emotional responses in early life, whether labelling an object with negative emotionality can diminish toddlers' attentional response evoked by the negative object during retrieval, and how the cognitive processing differs when toddlers learn label-object versus emotion-object associations could be meaningful directions to investigate.

5.6 Summary and Conclusion

Overall, the current work provides initial evidence of how perceived emotions affect word learning in toddlers. The toddlers' word learning was affected by the perceived emotions: the negative expressions captured more attention compared to the neutral and positive ones during the learning process and promoted 24-month-olds' retention of newly-learned label-object associations; but, in toddlers older than 30 months, like in adults, their word learning outcome was not affected by the affects perceived during learning, indicating a development of learning and memory ability. Moreover, the findings that negatively conditioned objects interfered with target recognition during the test part and toddlers only associated negative affect with the corresponding objects provide evidence of the presence of a negativity bias in toddlerhood. Furthermore, toddlers' looking in the retention tests might reflect a competition for attention between the target and distractor salience and the development of top-down control to overcome the negativity bias and sustain attention to the target. In addition to word learning, we also found that the collection of preferential looking only is not as reliable as the collection of both looking and pointing as the indices of retention in the presence of salient distractors. Therefore, the thesis illustrates the impact of perceived emotions on toddlers' word learning via the lens of attention and points out a methodological consideration regarding the choice of indices of retention in the word learning studies.

In sum, the current work indicated that perceived emotions influence the early learning of label-object associations in terms of attention and memory with the negative affect being the most influential compared with the neutral and positive affect. Nevertheless, the effect caused by the negative affect on attention and memory wanes with individuals' development because of, perhaps, the maturation of top-down attentional control and memory system.

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