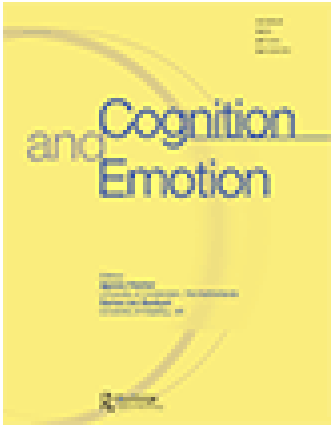

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Memory for positive, negative and neutral events in younger and older adults: Does emotion influence binding in event memory?

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BRIEF REPORT

Memory for positive, negative and neutral events in younger and older adults: Does emotion influence binding in event memory?

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When remembering an event, it is important to remember both the features of the event (e.g., a person and an action) and the connections among features (e.g., who performed which action). Emotion often enhances memory for stimulus features, but the relationship between emotion and the binding of features in memory is unclear. Younger and older adults attempted to remember events in which a person performed a negative, positive or neutral action. Memory for the action was enhanced by emotion, but emotion did not enhance the ability of participants to remember which person performed which action. Older adults were more likely than younger adults to make binding errors in which they incorrectly remembered a familiar actor performing a familiar action that had actually been performed by someone else, and this age-related associative deficit was found for both neutral and emotional actions. Emotion not only increased correct recognition of old events for older and younger adults but also increased false recognition of events in which a familiar actor performed a familiar action that had been performed by someone else. Thus, although emotion may enhance memory for the features of an event, it does not increase the accuracy of remembering who performed which action.

Keywords: Emotion; Binding; Event memory; Eyewitness memory; Unconscious transference.

Event memory depends on both memory for the features of the event, such as an action and a person, and memory for the connections between features, such as which person performed which action. Kersten, Earles, Curtayne, and Lane (2008) proposed that this association of people with their actions is an example of binding in memory. We proposed that features of the event

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(e.g., the person and the action) are represented in separate feature maps in memory. Thus to accurately remember an event, a person must also represent in memory the associations among these features. Just as with the binding of visual features in perception (e.g., Treisman & Schmidt, 1982), binding errors in event memory can occur when a feature from one memory trace is incorrectly associated with a feature from another memory trace. Thus, a person may correctly remember a familiar person and may correctly remember a familiar action, but the person may still incorrectly remember which person performed which action. When someone incorrectly remembers a familiar person performing an action that was actually performed by someone else, this phenomenon is called unconscious transference (Loftus, 1976).

Unconscious transference errors in event memory can make interactions with others difficult. A person may try to repay the wrong person, tell a story to a person who has already heard it, incorrectly remember who won at bridge, or even wrongly accuse someone of failing to return a borrowed item. The correct binding of people with their actions is also crucial for eyewitness testimony. When eyewitnesses in court make unconscious transference errors and incorrectly accuse a familiar person of committing a criminal action that was actually performed by someone else, the accused person may go to prison (e.g., Doyle, 2005).

We have provided extensive evidence that eyewitnesses frequently incorrectly associate one person with the actions of another person (e.g., Earles, Kersten, Curtayne, & Perle, 2008; Kersten & Earles, 2010; Kersten, Earles, & Berger, in press; Kersten, Earles, & Upshaw, 2013; Kersten et al., 2008). One difference between our studies on binding in event memory and other studies on eyewitness memory (e.g., Wells & Pozzulo, 2006) is that the actions in our previous studies did not have an emotional component.

Influence of emotion on memory for features

There is convincing evidence that emotion can improve memory (Holland & Kensinger, 2013), and memory for negative events is often better than memory for positive events (Kensinger, 2009). Negative and positive stimuli are usually more arousing than neutral stimuli. For example, Wang et al. (2013) found that positive and negative faces were more arousing than neutral faces. Mather and Sutherland's (2011) arousal-based competition model predicts that memory for the most important details of an event will increase as emotional arousal increases. When presented with information, people may focus more attention on information high in emotional arousal (Leclerc & Kensinger, 2008), and people often remember information high in emotional arousal better than information low in emotional arousal (MacKay et al., 2004).

In addition to the influence of emotional arousal, emotional valence may impact memory even in the absence of differences in arousal. For example, Adelman and Estes (2013) found that positive and negative emotional valence enhanced memory even when the to-be-remembered items were words that were not arousing. Most stimuli with emotional valence, however, are also more emotionally arousing than neutral stimuli (e.g., Wang et al., 2013).

In the current study, we created positive, negative and neutral events in order to examine the effects of emotion on event memory. The events used were intended to be typical of positive, negative and neutral actions that one would encounter in everyday life. Thus, we expected that the positive and negative actions would be more emotionally arousing than the neutral actions. We predicted that features of emotional events would be remembered better than features of neutral events.

Influence of emotion on binding ability

Research on the effects of emotion on associative information suggests a complex relationship. Mather (2007) suggested that when objects are emotionally arousing, attention is focused more intensely on those objects, and thus emotional arousal can increase the binding of the objects in memory. However, emotionally arousing objects

can also attract so much attention that they can provide interference during encoding and actually hinder memory for associations between objects. In particular, if one object is emotionally arousing and the other is not, attention may focus on the emotionally arousing object at the expense of attention to other information present, thus inhibiting the binding of the focal object with other contextual cues. This hypothesis is consistent with research on the weapon focus effect that has concluded that the presence of a weapon in an event decreases memory for other features, such as the identity of the people in the event (see Fawcett, Russell, Peace, & Christie, 2013, for a meta-analysis). Mather et al. (2006) found that emotional arousal elicited by target pictures decreased memory for the locations of the pictures. This result suggests that emotional arousal can cause people to focus on the to-be-remembered items at the expense of contextual cues associated with those items.

In the current study, we examined the ability of participants to associate a person with an action that was either positive, negative or neutral. One possibility was that emotion would lead to an overall increase in the memorability of the event, enhancing the ability of the participant to remember the association between a person and an action and thus decreasing binding errors. An alternative possibility, however, was that attention would be focused on the most salient, emotionally laden feature of an event. This could increase the memorability of that individual feature but could inhibit the association of that feature with other, more peripheral features of the event, thus potentially increasing unconscious transference errors.

Age differences in associative memory

There is convincing evidence that older adults have more difficulty than younger adults binding features in memory (e.g., Naveh-Benjamin, 2000). In a meta-analysis of 90 studies, Old and Naveh-Benjamin (2008) found a larger effect of age on memory for associations between items than on memory for item information. We have demonstrated that this age-related associative memory deficit is present in event memory. In Kersten et al. (2008, 2013) and Kersten and Earles (2010), participants were shown a series of events in which people performed actions. Older adults were significantly more likely than younger adults to make unconscious transference errors in which they incorrectly remembered a familiar person performing a familiar action that had actually been performed by someone else, and this effect remained when younger and older adults were matched on their ability to recognise the individual features of the event (i.e., the actor and the action) by using a longer retention interval for younger than for older adults.

The relation between emotion and age differences in associative memory is unclear. Nashiro and Mather (2011a) found that younger adults, but not older adults, were better able to bind together pictures of objects with their locations when the pictures were positive or negative rather than neutral, but emotion actually hindered the ability of both younger and older adults to bind together objects with abstract shapes. Using an easier memory task, however, Nashiro and Mather (2011b) found that emotional arousal increased the binding of pictures with their locations in both younger and older adults. Thus, the difficulty of the associative task may be important in predicting the effects of emotion on age differences in associative memory.

The effects of emotion on age differences in unconscious transference may be similar to the effects on age differences in associative cued recall. Murray and Kensinger (2013) found that an encoding task that encouraged participants to form a single image that integrated two words in a pair enhanced older adults' associative memory for positive and negative word pairs but not non-emotional word pairs. For younger adults, on the other hand, the picture integration task enhanced the cued recall of non-emotional words more than emotional words. There was no difference between positive and negative word pairs.

The effects of emotion on age differences in unconscious transference errors may also be similar to the effects of emotion on age differences in source memory. In event memory, the person may be considered to be the source of the action.

Davidson, McFarland, and Glisky (2006) found no effect of emotion on source memory by younger or older adults, but May, Rahhal, Berry, and Leighton (2005) found that older adults had better source memory for emotional than for non-emotional information.

Thus, it was not clear whether emotion would enhance the binding or inhibit the binding of people with their actions by younger and older adults. Emotion may enhance the integration of a person with his or her action, which could decrease age differences in unconscious transference, or emotion might be distracting and detract from the integration of the person with his or her action, which could increase age differences in unconscious transference.

METHOD

Participants

Participants were 30 Florida Atlantic University (FAU) undergraduate students (M_{age} = 24.03, *SD* = 8.77) who received course credit and 24 older adults (M_{age} = 70.04, *SD* = 7.70) from FAU Lifelong Learning courses who received a $20 gift card. An a-priori power analysis conducted using G*Power 3 (Faul, Erdfelder, Lang, & Buchner, 2007) determined that 46 participants were needed to detect an interaction of age and event type. An effect size of .3 and correlation of .25 among repeated measures were assumed based on the results of Kersten and Earles (2010). A sample size of 24 per age group was selected in order to balance participants across three list conditions. Six additional younger adults who signed up to participate were included.

The older adults were well educated with an average of 16.33 (*SD* = 3.36) years of education. Both younger and older adults were healthy with an average health rating of 4.31 (*SD* = .70) out of 5 for the younger adults and 4.08 (*SD* = .88) for the older adults. As expected, older adults scored significantly higher (*M* = 36.08, *SD* = 2.15) than younger adults (*M* = 27.47, *SD* = 3.50) on the Shipley (1986) vocabulary test, $t(52) = 10.56$, $p < .001$. The results of the vocabulary test suggest that the older participants were a good match for the younger participants in terms of intelligence relative to their age mates, with vocabulary scores typically increasing with age in college-educated populations (e.g., Earles & Kersten, 1999).

Materials

We generated 30 negative, 30 positive and 30 neutral actions (see Appendix).

In a pilot study, 10 people were given a random list of the 90 actions and asked to rate the emotional valence of each on a 7-point scale (1 = very negative, 2 = negative, 3 = mildly negative, 4 = neutral, 5 = mildly positive, 6 = positive, 7 = very positive). The range for negative events was 1.09–2.91 (*M* = 2.22, *SD* = .45), for neutral events was 3.45–4.45 (*M* = 4.08, *SD* = .20), and for positive events was 5.18–6.73 (*M* = 5.77, *SD* = .37).

Twelve people were given a random list of the 90 actions and asked to rate the level of arousal elicited by each on the 9-point Self-Assessment Manikin scale (Lang, 1980). Arousal ratings for positive (*M* = 4.91, *SD* = 1.30) and negative events (*M* = 4.71, *SD* = .90) did not significantly differ, $t(11) < 1$. As expected, neutral events were significantly less arousing (*M* = 7.42, *SD* = 1.09) than negative, $t(11) = 9.39$, $p < .001$, and positive events, $t(11) = 12.73$, $p < .001$.

Each of 10 female actresses was filmed performing three negative, three neutral and three positive actions. Movies were on average 6.73s (*SD* = 4.18), and the lengths of negative, positive, and neutral events did not differ, $F(2, 85) < 1$.

Procedure

During encoding, each participant saw one of three sets of 20 negative, 20 positive and 20 neutral events presented in a random order and was asked to try to remember the events. Each participant saw each of the 10 actresses perform two of each type of action. Participants then completed a vocabulary test (Shipley, 1986) and a demographics questionnaire.

Following a one-week delay, each participant saw 30 old events (10 negative, 10 positive and

10 neutral) in which an actress was seen performing the same action that she had performed during encoding, 30 new action events (10 negative, 10 positive and 10 neutral) in which an actress was seen performing an action that had not been seen during encoding, and 30 conjunction events (10 negative, 10 positive and 10 neutral) in which an actress was seen performing an action that had previously been performed by someone else. For example, if at encoding Actress A dropped her ice cream, and Actress B stubbed her toe, at retrieval, Actress A might stub her toe. Events were presented in a new random order for each participant. Each of the 10 actresses was seen in one old, one conjunction and one new action event of each event type.

Following each event, participants were asked to respond yes or no to the question, "Did you see this person perform this action in the first part of the experiment?" They were then asked to rate their confidence as "just guessing", "pretty sure" or "absolutely sure".

Design and analysis

The independent variables were age (younger or older) and emotion (negative, neutral or positive). The dependent variables were recognition memory and binding ability. d' was used as a measure of discrimination of old from new action events and discrimination of old from conjunction events. Orthogonal planned comparisons were used to compare recognition of emotional events with recognition of neutral events for younger and older adults and to analyse the effects of emotion on the binding ability of younger and older adults. Confidence ratings were not analysed because many participants did not make any yes responses to one of the nine types of event (i.e., old negative, old neutral, old positive, conjunction negative, conjunction neutral, conjunction positive, new action negative, new action neutral, new action positive), and thus these participants could not be included in an analysis of the confidence with which participants accepted the different types of items.

RESULTS

The proportions of hits and false alarms for all conditions are in Table 1. The alpha level was set at .05 for all analyses.

Recognition performance

Recognition performance was assessed using d' as a measure of discrimination between hits to old events and false alarms to new action events. As suggested by Stanislaw and Todorov (1999), a loglinear transformation, involving the addition of .5 to the number of hits and false alarms and the addition of 1 to the number of trials, was used because some participants had a hit rate of 1 or false alarm rate of 0 for one of the conditions.

Table 1. *Proportion of hits and false alarms across conditions*

	Negative		*Neutral*		*Positive*	
	M	SD	M	SD	M	SD
Hits to old events						
Younger	.84	.13	.74	.18	.81	.17
Older	.78	.16	.65	.20	.76	.18
False alarms to conjunction events						
Younger	.51	.20	.44	.19	.48	.17
Older	.62	.18	.49	.20	.58	.20
False alarms to new action events						
Younger	.08	.11	.14	.14	.09	.12
Older	.13	.19	.27	.28	.20	.19

Recognition performance across age group and emotion condition is shown in Figure 1.

Orthogonal comparisons using d' as the dependent measure were conducted to examine the effects of emotion on recognition performance. Younger adults recognised significantly more events than older adults, $F(1, 52) = 14.63$, $MSE = .259$, $p < .001$, $\eta_p^2 = .220$. Participants were significantly more likely to recognise emotional (positive and negative) than neutral events, $F(1, 52) = 49.51$, $MSE = .358$, $p < .001$, $\eta_p^2 = .488$, and there was no significant interaction between emotion and age, $F(1, 52) = 2.25$, $MSE = .358$, $p = .140$, $\eta_p^2 = .041$. There was a non-significant trend for participants to recognise negative better than positive events, $F(1, 52) = 3.76$, $MSE = .489$, $p = .058$, $\eta_p^2 = .067$. There was no significant interaction between emotion (positive or negative) and age, $F(1, 52) < 1$. Both negative and positive emotion, therefore, increased the discrimination of old from new action events for both older and younger adults.

Binding ability

Binding ability was assessed using d' as a measure of discrimination between hits to old events and false alarms to conjunction events. The same loglinear transformation was used. The discrimination between hits to old events and false alarms to conjunction events across age and emotion condition is shown in Figure 2.

Orthogonal comparisons using d' as the dependent measure were used to examine the effects of emotion on binding ability. Older adults made significantly more binding errors than younger adults, $F(1, 52) = 18.86$, $MSE = .130$, $p < .001$, $\eta_p^2 = .266$. Participants were not significantly more likely to make binding errors for emotional (positive and negative) events than for neutral events, $F(1, 52) < 1$, and there was no significant interaction with age, $F(1, 52) < 1$. Participants were also not significantly more likely to make binding errors for negative than for positive events, $F(1, 52) < 1$, and there was no significant interaction with age, $F(1, 52) < 1$. Because the effect sizes for the interactions involving emotion are essentially zero, we are confident that the finding of Kersten and Earles (2010) that older adults have more difficulty than younger adults in binding actors with their actions held equally well for negative, positive and neutral events.

DISCUSSION

Emotion and recognition of event features

Consistent with previous research on the effects of emotion on memory for other types of materials (e.g., Holland & Kensinger, 2013), recognition of

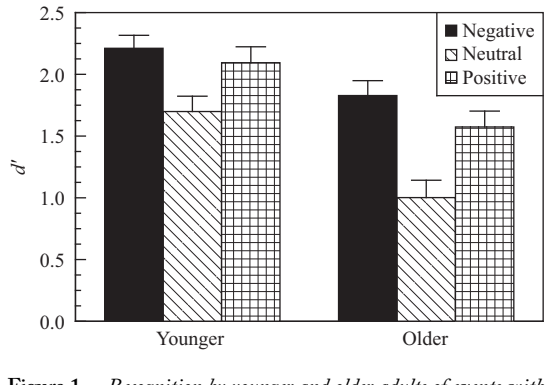

Figure 1. *Recognition by younger and older adults of events with negative, neutral and positive valence as measured by the discrimination of old events and new action events.*

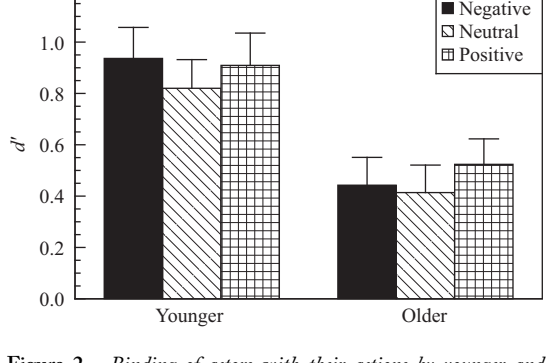

Figure 2. *Binding of actors with their actions by younger and older adults for events with negative, neutral and positive valence as measured by the discrimination of old events and conjunction events.*

emotional actions was better than recognition of neutral actions. Discrimination between old and new action events was larger for emotional than for neutral events for both younger and older adults, demonstrating that emotion enhanced memory for actions regardless of age. There was a nonsignificant trend for negative emotion to enhance memory for actions more than positive emotion which is consistent with Kensinger's (2009) hypothesis that negative emotion enhances memory more than positive emotion.

Positive and negative actions are by their nature more arousing than neutral actions and are likely to be more arousing than the words or pictures of objects that are often used in research on the effects of emotion on memory. Emotional arousal can influence memory consolidation processes in the brain. Positive or negative emotional arousal can lead to the release of the adrenal hormone epinephrine which increases the release of norepinephrine in the amygdala, thus increasing memory consolidation (McIntyre, McGaugh, & Williams, 2012).

As expected, the emotional actions in the current study were rated as more arousing than the neutral actions. However, neither the positive nor the negative actions were rated as highly arousing. Future research should examine the effects of level of arousal on memory for emotional events. Extremely emotional actions, such as stabbing someone, may be remembered better than less emotional actions such as those used in the current study.

Emotion and binding ability

We found that emotion did not increase the ability of participants to bind actors with the actions they had performed. Emotion not only increased the proportion of correct yes responses to old events but also increased the proportion of incorrect yes responses to conjunction events, so emotion did not increase the discrimination of old from conjunction events. Instead, discrimination between old and conjunction events was similar for negative, positive and neutral events.

In some previous research, emotional arousal was found to decrease binding ability. For example, in Nashiro and Mather (2011a) the binding of objects with abstract shapes was more difficult when the objects were emotionally arousing. Mather (2007) proposed that emotionally arousing objects could attract attention to the object to such an extent that it took attention away from contextual features, thus hindering the binding of a feature with its context.

Other research provides evidence that emotional arousal can increase binding. For example, in Nashiro and Mather (2011a) younger adults were more successful at binding a picture with its location in a grid when the object pictured was emotionally arousing, and Nashiro and Mather (2011b) showed that emotional arousal could enhance the binding of pictures with locations for older adults.

In the current study, however, the enhanced memory for the features of the event due to positive and negative emotion did not detract from or enhance memory for the association between actors and their actions. Our results may differ because the actresses in the current study are central to the event. Rather than being unassociated contextual context, the actress herself is causing the emotional action to happen.

Although discrimination of old and conjunction items was not affected by negative or positive emotion, the rates of both correct recognition of old items and false recognition of conjunction items were increased by the presence of emotion. Thus, the absolute level of false recognition of the conjunction items, when considered in isolation, was actually higher in the presence than in the absence of emotional content. A familiar actor, coupled with an emotional action, led to a greater rate of acceptance of that combination of actor and action, regardless of whether or not that actor and action had appeared together at encoding.

Age-related associative deficit

Older adults have more difficulty than younger adults binding together people with their actions (Kersten et al., 2013). Kersten and Earles (2010) provided evidence that ageing may lead to an impairment in binding abilities that is independent

of any impairment in the attention demanding executive processes involved in remembering the individual features of an event. In Kersten and Earles (2010), younger adults who were distracted or under time pressure exhibited binding abilities that were commensurate with their memory performance for the individual features of an event, whereas older adults exhibited binding deficits above and beyond any deficits in feature memory. The results of the current study extend these findings by demonstrating that this age-related associative deficit in memory for events is also present when the to-be-remembered events are positive or negative. In particular, emotion did not affect age differences in discrimination of old and conjunction items.

These results are consistent with the findings of Davidson et al. (2006) that emotion did not affect source memory for younger or older adults. In May et al. (2005), however, older adults remembered the source of emotional information (i.e., safety of a food item) as well as younger adults, and the authors suggested that the emotional information engaged the attention of the older adults. Our results may differ from those of May et al. (2005) because their manipulation of emotion was different from the manipulation used in most studies. In May et al. (2005) participants rated the safety or the quality of a food item, and food safety may have been more important to older than to younger adults. In the current study, both older and younger adults showed enhanced memory for the features of the emotional relative to the neutral events, so the attention of both younger and older adults seemed to be enhanced by our manipulation of emotion.

Our results are consistent with the theory that the hippocampus represents a point of convergence of "what" and "where" information in memory (Eichenbaum, Sauvage, Fortin, Komorowski, & Lipton, 2012). The hippocampus may represent conjunctions of actor information with information about the context in which that actor was encountered. When later presented with a test item involving that same context, these conjunctive hippocampal representations may allow one to reactivate the previously associated actor. If the retrieved actor representation matches the actor who is currently seen in the test item, this would encourage participants to accept the test item as old, whereas if the retrieved representation does not match, it would encourage participants to reject the test item. Ageing has been associated with declines in the structure and functioning of the hippocampus, however (see e.g., Cabeza, 2006), and thus older adults may be less successful than young adults at remembering the context in which an actor had appeared.

Implications for eyewitness testimony

The present findings have important implications for eyewitness testimony. We demonstrated that although eyewitness memory for the action itself is better for emotional than for neutral events, unconscious transference errors frequently occur even for events that are emotional. We also demonstrated that older eyewitnesses to an event are especially susceptible to unconscious transference errors regardless of emotional content. The combination of enhanced memory for emotional actions, coupled with reduced performance at binding those actions with the actual actors who had performed those actions, makes older adults particularly likely to exhibit unconscious transference errors involving emotional actions.

CONCLUSIONS

Emotion increased memory for actions in events for both younger and older adults. Emotion did not, however, enhance the binding of actions with the people who performed them for either younger or older adults. Older adults made more binding errors than younger adults, regardless of emotional content. Because emotion increased memory for the actions without concurrently benefiting the binding of those actions with the actors who performed them, both young and older adults were actually more likely to make unconscious transference errors when that action involved negative or positive emotion.

Disclosure statement

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APPENDIX

List of actions

Negative actions

Scooping up dog poop
Burning hand on a stove
Getting mosquito bites
Seeing a sick person crouching over the toilet
Seeing a wounded person in a sling
Falling on roller skates
Losing money in vending machine
Standing by a car with a flat tire
Sitting in wheelchair with broken leg
Spilling potato chips
Stomping on a roach
Stubbing toe
Getting a parking ticket
Receiving a D on a paper
Breaking a necklace
Spilling a drink
Getting locked out of a car
Computer freezing up
Rubbing head with a headache
Putting flowers on a grave

Plunging a toilet
Hitting finger with a hammer
Cutting finger while cooking
Cleaning up mud tracked on the floor
Ice cream falling off a cone
Missing a shot in basketball
Being unable to open a jar
Car will not start
Dropping papers that scatter on the floor
Opening a carbonated beverage that spills everywhere

Positive actions

Receiving a good letter in the mail
Playing a piano

Baking cookies
Swinging
Winning money from a scratch off ticket
Smiling/laughing while talking to someone on the phone
Laying down a towel at the beach under a beach umbrella
Petting a puppy
Dancing
Taking a photograph
Smelling a rose
Completing a puzzle
Reading a book by the pool
Playing cards
Blowing out candles on a birthday cake
Winning a game of checkers
Lying on a hammock
Looking at a travel book to plan a vacation
Hugging a kitten
Opening a card on a bouquet of flowers
Eating a cookie
Receiving a new car
Sliding down the slide
Flying a kite
Opening a present
Opening an envelope with cash in it
Picking flowers
Riding on a rocking dinosaur at a park
Playing pool
Building a sandcastle

Neutral actions
Tying shoes
Stapling papers
Folding a napkin
Opening refrigerator
Pouring a drink
Cracking a nut
Lighting a candle
Reading newspaper
Opening a folder
Doing dishes
Stirring oatmeal
Getting in a car
Covering a bowl
Putting on gloves
Peeling a banana
Brushing teeth
Applying lotion
Measuring a line
Loading groceries into a car
Brushing hair
Opening a door
Washing hands
Setting a clock
Sharpening a pencil
Dialling a phone
Putting sugar in tea
Watering a plant
Throwing away paper
Applying nail polish
Climbing stairs