Memoir Dataset: Quantifying Image Memorability in Adolescents

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Abstract

Recent work shows that images differ in terms of their memorability, some stick in one's mind while others are forgotten quickly, and this phenomenon is consistent across observers. Previous research agrees that memorability is an intrinsic, continuous property of a stimulus that can be both measured and manipulated, however; this work has been limited to adults. In this study, we attempted to quantify image memorability in adolescents (11-18 years old) and determine if it differs from image memorability in adults. We selected images from the MemCat data set that are annotated with adult memorability scores. By running a visual memory game online, we quantified these images on their memorability in adolescents, and compared them to the adult scores. Our study finds that memorability rankings in adolescents and adults are strongly and significantly correlated. Moreover, the rankings of memorability by image category were also identical in both age groups, indicating that certain image categories are more consistently memorable for both adults and adolescents. Collectively, our results support previous research that suggests memorability is an intrinsic property of images that is consistent across viewers even with different developmental stages.

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Introduction

Every day, humans observe and interact with hundreds of images and scenes; whether it be on a cellphone, on television, or in print. While human memory has a massive capacity to remember images (Brady, Konkle, Alvarez, & Oliva, 2008), a vast majority of these images are forgotten, some immediately and some after variable lengths of time. Memorability is indeed a property intrinsic to all images that can be extracted, as well as predicted (Bainbridge, 2019; Bainbridge, Dilks, & Oliva, 2017; Borkin et al., 2013; Bylinskii, Isola, Bainbridge, Torralba, & Oliva, 2015; Isola, Xiao, Torralba, & Oliva, 2011; Khosla, Raju, Torralba, & Oliva, 2015; Rust & Mehrpour, 2020), or manipulated (Goetschalckx, Andonian, Oliva, & Isola, 2019).

We follow the definition of image memorability provided in Isola, Xiao, Parikh, Torralba, and Oliva (2013) as the probability that a repetition of a photograph will be detected by an observer when presented amidst a stream of images at various intervals. Isola, Xiao, et al. (2011) introduced their large-scale visual memory game used to test and quantify the memorability of images and hosted it on Amazon Mechanical Turk to allow for crowdsourcing. This experiment has since been replicated many times (Goetschalckx & Wagemans, 2019; Isola et al., 2013; Khosla et al., 2015) and has formed the foundations of measuring image memorability. Memorability is a critical property of images as it has been found to be an automatic, unconscious form of memory that is disparate from other cognitive processes that influence memory behaviour (Bainbridge, 2020; Bainbridge et al., 2017; Mohsenzadeh, Mullin, Oliva, & Pantazis, 2019). Therefore, memorability cannot be overridden by an individual: one cannot attempt to forget a memorable image, or remember a forgettable image (Bainbridge, 2020).

To understand memorability, the visual memory game described above has been used to assign memorability scores to thousands of images, and it has been shown that certain image features can be extracted and linked to memorability. Specific object categories (people, animals, and vehicles) as well as scene categories (indoor scenes) are more memorable than others (Goetschalckx & Wagemans, 2019; Isola, Parikh, Torralba,

& Oliva, 2011; Isola et al., 2013; Khosla, Xiao, Isola, Torralba, & Oliva, 2012; Perera, Tal, & Zelnik-Manor, 2019). In fact, Isola et al. (2013) have reported that the scene category captures most of what makes an image memorable. They also demonstrated that high-level semantic attributes, such as spatial layout, dynamics, and location, are associated with memorability. Saliency and contrast have been shown to be important factors, meaning images with specific points of focus are more memorable (Isola, Parikh, et al., 2011; Mancas & Le Meur, 2013). Interestingly, image aesthetics and perceived popularity have shown little to no correlation with memorability, despite being correlated to each other (Goetschalckx & Wagemans, 2019; Isola, Parikh, et al., 2011; Khosla et al., 2012). Similarly, participants' perceived estimates of image memorability have a low correlation with their true memorability (Isola, Xiao, et al., 2011), as most people wrongly assume more beautiful and aesthetic images will be easier to remember. Negative emotions are more memorable than positive emotions, so images that evoke disgust, for example, would be remembered better than those that conjure feelings of amusement (Isola, Parikh, et al., 2011). Colours and colour features such as saturation and hue have little correlation with memorability. Non-semantic image statistics, such as the number of objects in the image, are also not effective predictors of memorability on their own (Isola et al., 2013).

While extensive work has been done to study image memorability in adults, no studies exist regarding the adolescent (ages 11-18) population and the differences in image memorability across different age groups. Generally, effective quantification of memorability may be useful for learning purposes, for marketing use (producing memorable advertisements), and for powerful communication and presentation of information. Specifically in adolescents, the ability to maximize visual memorability has profound implications for education, particularly in youth with certain developmental and educational disabilities. This study aims to fill this gap by assigning memorability scores derived from adolescents to images and comparing them to memorability scores derived from adults. We investigate the intrinsic nature of image memorability and whether conclusions from research done in adults can be extrapolated to the adolescent

population.

Materials and Methods

Stimuli

The stimuli in this study were selected from MemCat (Goetschalckx & Wagemans, 2019), a recently published image memorability dataset. The MemCat dataset is publicly available and includes 10,000 images that have been annotated with adult memorability scores. We used adult memorability scores provided by MemCat as a point of comparison to the adolescent memorability scores we obtained in this study. A special feature of the MemCat dataset (compared to other image memorability datasets (Bainbridge, Isola, & Oliva, 2013; Borkin et al., 2013; Bylinskii et al., 2015; Isola et al., 2013; Khosla et al., 2015)) is its hierarchical category structure: it features five main categories (animals, food, landscapes, sports, and vehicles), each with at least 20 subcategories (such as sheep, salad, waterfall, basketball, and airplane). This allowed us to robustly analyze the effects of these categories on memorability, as done previously in adults (Goetschalckx & Wagemans, 2019; Isola, Parikh, et al., 2011; Isola et al., 2013; Khosla et al., 2012; Perera et al., 2019). For our adolescent memorability dataset, which we call the Memoir dataset, we randomly sampled 1,000 images from the MemCat dataset equally from each category and from the full range of memorability scores provided in MemCAT. Each of the selected images was reviewed by the authors to make sure they were appropriate for the target population (adolescents).

Experiment Design

To measure image memorability, we conducted an online visual memory game and recruited participants through Amazon Mechanical Turk. Following previous memorability work (Akagunduz, Bors, & Evans, 2019; Bylinskii et al., 2015; Goetschalckx & Wagemans, 2019; Isola et al., 2013; Khosla et al., 2015), the visual memory game was a repeat decision task (see schematic in Figure 1). Participants were shown a sequence of images, each displayed for 600 ms with 800 ms inter-stimulus

intervals, and were instructed to press the spacebar when they encountered an image that they remembered being shown previously. The inter-stimulus intervals consisted of a blank white screen with a centered black fixation cross and were shown for 800 ms. Participants received feedback on their performance during the experiment. If participants correctly identified a target image repeat, a green border appeared around the image, whereas in the case of a false alarm, a red border appeared around the image. At the start of the experiment, participants were shown a short demo video to ensure they understood the instructions.

The experiment comprised of 10 blocks, each lasting around 5 minutes. Participants could complete a maximum of 10 blocks or exit the game at any time. Each block included 200 images comprised of 66 targets (and 66 target repeats), 56 fillers, and 12 vigilance repeats. Target images were repeated exactly one time and at variable time intervals (after 19-149 filler images). The filler images comprised everything in between the targets and were only displayed once, with occasional vigilance repeats of fillers being shown to ensure participants were alert (Isola, Xiao, et al., 2011). Vigilance repeats were used to ensure that the participants were paying attention and participating meaningfully, and were repeated after 0 to 2 images. This experiment allowed for the calculation of image memorability scores as the percentage of correct detections by participants (see Computing Memorability Scores).

Strict criteria were also used to ensure participants were engaged in the game to guarantee a high quality of results. Following Isola, Xiao, et al. (2011), the visual memory game automatically ended when a participant fell below a 50% success rate on the block's vigilance repeat detection or above a 50% error rate on the non-repeat images ("false alarms"). If this happened, all data collected from the participant from the current block was discarded. As well, if a participant did not complete a level due to quitting the experiment willingly, all data from the last block was also discarded. After quality exclusions, an image's number of responses (N_{resp}) was 94, on average.

Participants

A total of 273 participants aged 11-18 years were recruited from Amazon Mechanical Turk, completing an average of six blocks. 143 of these participants (52%) identified as male and 130 (48%) identified as female. After quality exclusions (see Experiment Design), 11% of the blocks were excluded from the analysis. 61% of these excluded blocks were due to participants being kicked out of the experiment and the remaining 39% of the excluded blocks were from participants that quit the experiment intentionally in the middle of a block. A total of 96 participants completed all 10 blocks.

Participants consented to their participation following the protocol approved by Western University Research Ethics Board. Participants were compensated for their participation in the study according to the number of blocks they completed.

Computing Memorability Scores

Following MemCat, we computed two different memorability scores for each image:

$$\frac{H}{N_{resp}} \quad (1)$$

$$\frac{H - F}{N_{resp}} \quad (2)$$

where H is the number of participants recognizing the image, F is the number of participants making a false alarm (ie., pressing the spacebar when the image is presented for the first time), and N_{resp} is the total number of participants having been presented with the image. Measure 1 is simply the proportion of participants that recognized the image at the second showing. Measure 2 is similar, but also penalizes the score for false alarms. This is following Khosla, Bainbridge, Torralba, and Oliva (2013), who proposed that accounting for false alarms (button press when an image is shown for the first time) in the memorability score calculation reduced the noise in the data and lead to more reliable results.

Results

Adolescent Memorability Scores

Figure 2 compares the distributions of memorability scores in adolescents calculated per the two distinct memorability measures. Memorability scores were higher when calculated without the false alarm correction ($M_{H/N_{resp}} = 0.74$; $M_{(H-F)/N_{resp}} = 0.61$). One-way between-subjects ANOVA revealed that there was a significant difference in memorability scores between the five main categories using both memorability measures ($\alpha = 0.05$) [$(H/N_{resp} : F(4, 999) = 49.91, p < 0.001$] [$(H - F)/N_{resp} : F(4, 999) = 48.19, p < 0.001$].

Consistent with previous research in adults (Goetschalckx & Wagemans, 2019), images in the food category were the most memorable, followed by animal, then sports, vehicle, and finally, landscape. Table 1 summarizes the mean memorability scores in each category from both measures as well as their respective standard deviations. The significant and consistent trends in memorability by category suggested that broad image category (here the five main categories) explains a large amount of the variance in adolescent memorability scores. The ANOVA effect size (η^2) revealed that 44% of the variance in H/N_{resp} memorability scores is explained by image subcategory, as well as 49% of the variance in the $(H - F)/N_{resp}$ memorability scores. However, there is also a rather large degree of within category variation (see Figure 2) that is consistent across the five categories. Therefore, other factors may exist that contribute to the differences in image memorability scores.

Reliability of Adolescents Memorability Scores

Following previous memorability work (Goetschalckx & Wagemans, 2019; Isola et al., 2013; Khosla et al., 2015), we examined the reliability of the calculated memorability scores to determine if these factors were consistent across participants. We measured the consistency and reliability of the computed memorability scores by splitting the participants into two independent sets, computing their respective memorability scores separately for each set, and calculating the Spearman's rank

correlation between the two sets (see Figure 3). To better understand the effect of the number of participants on the correlation, we also randomly down-sampled our data to a lower number of data points per image. We repeated each analysis for 25 random splits of the participant pool and averaged the Spearman’s rank correlation across the splits. Figure 3 displays the results of this analysis using both memorability measures. There is a high degree of consistency across participants both within categories and for the data as a whole, although, the consistency was slightly lower when observing individual categories (possibly due to a decreased availability of data points). Generally, the rank correlations were higher in the H/N_{resp} scores. Using all available data points and across all categories, the mean split-half rank correlation using this measure was 0.73 (with a mean N_{resp} of 94). This is comparable to MemCat, who reported an overall reliability of 0.78 (with a mean N_{resp} of 99) (Goetschalckx & Wagemans, 2019). Correlations were slightly lower within the categories: 0.70 (landscape), 0.69 (sport), 0.68 (food), 0.67 (vehicle), and 0.63 (animal). As the split-half rank correlation is an underestimate of the full-length reliability test (due to reliability increasing with more data points), we applied the Spearman-Brown formula (Brown, 1910; Spearman, 1910) to convert these split-half estimates into total reliabilities. Using this formula, we achieved the following memorability score reliabilities: 0.84 (all), 0.82 (landscape), 0.82 (sport), 0.81 (food), 0.80 (vehicle), and 0.77 (animal).

As expected, the $(H - F)/N_{resp}$ memorability scores tended to be lower, on average. Using all available data points and across all categories, the mean split-half rank correlation using this measure was 0.68 (with a mean N_{resp} of 94). Applying the Spearman-Brown formula to estimate the memorability score reliability from the split-halves, the total reliability was 0.81. In the individual categories, this was once again lower: 0.80 (sports), 0.78 (food), 0.76 (landscape), 0.75 (animal), and 0.74 (vehicle).

In sum, the strength of these correlations indicates the high reliability of measured memorability scores across the adolescent population, in spite of individual differences and other sources of noise.

Comparing Adolescent and Adult Image Memorability Scores

Due to the increased reliability of the memorability scores calculated using the H/N_{resp} measure, we restrict the following analysis to these scores. We discuss the $(H - F)/N_{resp}$ scores and false alarm ratios separately in the next section, and the associated figures are available in the supplementary material. Figure 4 displays the distribution of H/N_{resp} memorability scores in both the adolescent and adult populations for each of the five broad image categories. It also shows the global mean memorability score for each of the populations as a horizontal line. Mean memorability scores in adolescents ($M = 0.74, SD = 0.12$) were comparable to mean memorability scores in adults ($M = 0.76, SD = 0.14$). As well, the Spearman’s rank correlation coefficient between the adolescent and adult data was very high ($\rho = 0.76, p < 0.001$) and close to the reliability correlation we established in the previous section. As evident in Figure 4, the category rankings are also identical in adolescents and adults. In both age groups, the food category is the most memorable, followed by animal, sports, vehicle, and landscape. Figure 5 visualizes the rank correlation between the two age groups and how the memorability scores of each respective image differs between them. For the most part, points are evenly distributed around the equality line and exhibit a strong positive correlation. The rank correlations were lower within the categories (as expected due to the lower number of data points): 0.73 (vehicle), 0.73 (food), 0.72 (sport), 0.71 (landscape), and 0.67 (animal).

Comparing Adolescent and Adult False Alarm Rates

Previous work (Bainbridge et al., 2013) has suggested that images with a high hit rate yet a low false alarm rate are “truly memorable”, while those that receive both a high hit rate and a high false alarm rate may simply conjure strong false memories. We aimed to determine whether similar images in adolescents and adults were truly memorable. To isolate these truly memorable images, we divided the images into four quadrants consisting of high/low hit rates ($HR = H/N_{resp}$) and false alarm rates ($FAR = F/N_{resp}$). Following Bainbridge et al. (2013), these quadrants were formed by

splitting the images along the median HR and FAR of the adolescent data (Figure 6).

We first note that false alarm rates, in general, were significantly higher in adolescents ($M = 0.13$, $SD = 0.066$) than in adults ($M = 0.057$, $SD = 0.051$); $t(1,000) = -42.81$, $p < 0.001$. This explains why, in the previous section, we observed a greater reduction in adolescent memorability scores and rank correlations than MemCat when using the memorability measure with the false alarm correction (see supplementary Figure S1). However, the Spearman’s rank correlation between false alarm rates in adolescents and adults was significant ($\rho = 0.55$, $p < 0.001$). We compared the quadrant assignment agreements between adolescents and adults to determine if the same images were truly memorable for both populations. The truly memorable images (high HR, low FAR) had the highest percentage agreement of 62.1%, compared to a chance 25%. Memorable and familiar images (high HR and FAR) had an agreement of 55%, truly forgettable images (low HR and FAR) had an agreement of 59%, and the images which are commonly falsely remembered but rarely actually remembered (low HR, high FAR) had an agreement of 53%. Therefore, images are “truly memorable” to both adolescents and adults with a high degree of consistency.

As mentioned in the previous section, the overall Spearman’s rank correlation between the adolescent and adult memorability scores was 0.76. Table 2 summarizes the Spearman’s rank correlations between adolescent and adult memorability scores in each of the quadrants. The truly memorable images (high HR, low FAR) had a low correlation compared to the other quadrants ($\rho = 0.49$) without the false alarm correction, but the strongest correlation of the four quadrants ($\rho = 0.56$) with the false alarm correction. The rank correlations were lower here because the sample size in each quadrant was lower than when the rank correlation was calculated using all available data. The false alarm correction increased the rank correlation of the truly memorable images, but decreased that of the truly forgettable images. Applying the correction was effective in reducing the noise in the truly memorable images, but slightly reduced our overall rank correlation and reliability (as seen in the previous sections).

Discussion

Our findings support previous research that suggests memorability is an intrinsic property of images that is consistent across viewers. Memorability rankings were consistent across adolescents and adults, indicating that viewer age is not a factor in determining the memorability of images. This is consistent with previous findings that show memorability is intrinsic to the image, rather than the observer (Bainbridge, 2020; Bainbridge et al., 2013; Isola et al., 2013; Jaegle et al., 2019; Khosla et al., 2015). In addition to individual image rankings, category rankings are also consistent across adolescents and adults. Food images are the most memorable, while landscape images are the least memorable.

While the ranking of image memorability was similar in adolescents and adults, adolescents experienced significantly higher false alarm rates. Adolescence is widely recognized as a developmental period during which risk-taking and reward-seeking behaviours are increased. By the time they reach adulthood, adolescents' risk-taking declines due to structural and functional changes in the brain's cognitive control system (Steinberg, 2008; Yurgelun-Todd, 2007). The increased cognitive control that comes with the maturation of the brain (Casey, Getz, & Galvan, 2008) may explain the higher false alarm rates we observed in adolescents. Their increased impulsivity and need for immediate rewards combined with the rapid nature of the visual memory game caused adolescents to be less patient/cautious with their button presses than adults. Despite this, we find that for both adolescents and adults the same images are likely to fall into the "truly memorable" category. Taken together with the high rank correlation between the adolescent and adult memorability scores, we can conclude that memorability is highly consistent and reliable across these two age groups.

The ability to measure and manipulate memorability has extensive applications in many fields, such as education, marketing, and psychology. Specifically in adolescents, educators can make use of this insight to create educational material (for example, images in textbooks) that is more likely to be remembered. For example, learning examples making use of food images will be more optimal than those that make use of

vehicle images, as students are more likely to remember them visually. Developmental Coordination Disorder and Attention Deficit and Hyperactivity Disorder are two common neurodevelopmental disorders in school-aged adolescents (Delgado-Lobete, Pértega-Díaz, Santos-del Riego, & Montes-Montes, 2020). Evidence suggests that individuals with these conditions exhibit impairments in working memory (Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005); therefore, better understanding of the features that can optimize learning material could greatly improve recall, retrieval and retention in students to aid in learning.

Acknowledgement

This study was supported generously by the Canada First Research Excellence Fund (CFREF) through BrainsCAN, the Canadian Open Science Platform (CONP), and Western faculty of education internal grant.

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Category	$M_{H/N_{resp}}$	$SD_{H/N_{resp}}$	$M_{(H-F)/N_{resp}}$	$SD_{(H-F)/N_{resp}}$
All	0.74	0.12	0.61	0.13
Food	0.80	0.10	0.68	0.11
Animal	0.76	0.11	0.63	0.11
Sports	0.75	0.11	0.61	0.12
Vehicle	0.70	0.11	0.59	0.12
Landscape	0.66	0.12	0.52	0.12

Table 1

Mean memorability scores per category with and without false alarm correction. Number of images is n (all categories) = 1,000. n (animal) = 195, n (sport) = 242, n (food) = 209, n (vehicle) = 162, n (landscape) = 192.

Quadrant	$H/N_{resp} \rho$	$(H - F)/N_{resp} \rho$
High HR, low FAR	0.49	0.56
High HR, high FAR	0.39	0.39
Low HR, low FAR	0.61	0.50
Low HR, high FAR	0.54	0.55

Table 2

Spearman's rank correlation between adolescent and adult memorability scores per the two measures. Correlations are shown separately for each HR/FAR quadrant, created by taking the median of each in the adolescent data.

Figure 1. Design of experiment: images were displayed for 600 ms followed by an 800 ms blank screen with a fixation cross. Participants were instructed to press the spacebar when they recognized a second occurrence of any image.

Figure 2. Distribution of collected memorability scores in adolescents. (A) is the distribution with memorability scores computed as the hit rate across participants. (B) is the distribution with memorability scores computed as the hit rate across participants accounting for false alarms. The red horizontal line is the global mean memorability score for each of the populations ($M = 0.74$ and $M = 0.61$ for A and B, respectively). Number of images is $n = 1,000$ for both figures.

Figure 3. Split-half consistency across participants of the H/N_{resp} and $(H - F)/N_{resp}$ memorability scores as a function of N_{resp} . Estimates are based on 25 random splits. N_{resp} refers to the sum of data points per image, not the number of data points in one half during the split-half procedure.

Figure 4. Distribution of collected memorability scores in adolescents (A) and adults (B). Adult data is from the MemCat dataset (Goetschalckx & Wagemans, 2019). The red horizontal line is the global mean memorability score for each of the populations ($M = 0.74$ and $M = 0.76$ for adolescents and adults, respectively). $n = 1,000$ for both figures. See Supplementary Figure S1 for an equivalent analysis for the $(H - F)/N_{resp}$ scores.

Figure 5. Memorability scores per image in adolescent and adult populations, per the H/N_{resp} measure. Each dot represents one image. The diagonal line represents identical memorability scores in adolescents and adults. Points are equally distributed around the line for all categories. Rank correlation is highest in the Sport category (C) and lowest in the vehicle category (E). See Supplementary Figure S2 for an equivalent analysis for the $(H - F)/N_{resp}$ scores.

Figure 6. Scatter plot of hit rates (H/N_{resp}) and false alarms rates (F/N_{resp}) in adolescents. Black dashed lines represent the median values that divide the data into four quadrants of high/low HR/FAR.

Figure S1. Distribution of collected memorability scores in adolescents (A) and adults (B), per the $(H - F)/N_{resp}$ measure. Adult data is from the MemCat dataset Goetschalckx and Wagemans (2019). The red horizontal line is the global mean memorability score for each of the populations ($M = 0.61$ and $M = 0.70$ for adolescents and adults, respectively). $n = 1,000$ for both figures.

Figure S2. Memorability scores per image in adolescent and adult populations, per the $(H - F)/N_{resp}$ measure. Each dot represents one image. The diagonal line represents identical memorability scores in adolescents and adults. Points are equally distributed around the line for all categories. Rank correlation is highest in the Sport category (C) and lowest in the vehicle category (E).