**IMT School for Advanced Studies, Lucca**

Lucca, Italy

# The Role of Processing Fluency and Ambiguity in Cognitive, Affective, and Aesthetic Responses to Internet Memes and Mooney Images

PhD Program in Cognitive and Cultural Systems

Track In Cognitive, Computational, and Social Neurosciences

XXXVI Cycle

**By**

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**2025**

Contents

## Acknowledgements

When I applied to IMT, I wrote that life is an infinitely complex jigsaw puzzle with all living beings working on a small piece of the picture. I would first like to acknowledge and thank the universal force that keeps chaos at bay so that we humans can play our little games on Earth. Next, I would like to thank my family for giving me a special piece of themselves. I would like to thank my mother for giving me her faith and courage to move across the world and start life anew, my father for giving me his lifelong love for learning, and my little brother for giving me my first chance to be a mentor in life. I want to thank my grandmother Etenesh for giving me her sense of humor, my grandmother Tatiye for giving me her cleverness, and all my aunts and uncles for giving me their stories to carry with me as infinite motivation for my life. Furthermore, I would not be here if it wasn't for the incredible teachers I have had along the way. Thank you to Ms. Rumbold for giving me the gift of English by nurturing me in my critical window for language learning. Thank you to Mr. Slimak for my first introduction to the fascinating world of neuroscience. Thank you to my mock trial coaches, Ms. Cantone and Mr. Smith, for taking away any fear of public speaking and giving me a lifelong skill that has served me immensely. Thank you to all the social science teachers at Prospect High School for fanning the flames for my passion in this field. Speaking of fanning the flame, thank you to Prof. Nico Orlandi and Prof. Nicolas Davidenko for giving me the opportunity to start my research on internet memes at UC Santa Cruz. The work I did with the two of you was the first step to this dissertation. However, this dissertation would be empty without my supervisors Luca Ceccheti and Rolf Reber. Thank you to both of you for believing in this project from the start. Thank you, Luca, for guiding me through my annual panic attacks and for connecting me to our amazing colleagues at the University of Pisa. Thank you, Rolf, for your close attention that often highlighted my expert's curse and for hosting me in Oslo. Thank you to my three reviewers for your time, attention, and interest in the improvement of my dissertation. I want to thank all of my friends at IMT for keeping me sane for the past four years. Last but not least, I want to thank me for believing in me, for doing all this hard work, and never quitting.

Chapter 1 and Chapter 2 contains material from the publication:

Ayele, S. T., Cecchetti, L., & Reber, R. (2025). Ingredients for a good meme: Cognitive, emotional, and social factors of internet meme appreciation. Psychology of Aesthetics, Creativity, and the Arts. https://doi.org/10.1037/aca0000744

Chapter 3 contains material from the publication:

Ayele, S.T., Cecchetti, L., & Reber, R. (2024). Psychophysiological Differences in Fluent and Disfluent Internet Memes. OSF. https://doi.org/10.31234/osf.io/96bgm

The authors have used AI tools in the initial drafting of the thesis but have significantly revised and checked for accuracy of statements.

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## Publications

Ayele, S. T., Cecchetti, L., & Reber, R. (2025). *Ingredients for a good meme: Cognitive, emotional, and social factors of internet meme appreciation.* Psychology of Aesthetics, Creativity, and the Arts. https://doi.org/10.1037/aca0000744

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## Presentations

Recipe for a good meme. Beauty and Change Conference, Turin, Italy, 2022

Recipe for a good meme. *K & C Seminar*, Bologna, Italy, 2022

Recipe for a good meme. *Italian Association for Cognitive Science*, Genova, Italy, 2023

Psychophysiological differences between fluent and disfluent internet memes. *Beauty and Change Conference*, Turin, Italy, 2023

Optimal distinction in cyberspace Understanding Preferences for Local and Global Internet Memes on Facebook. *Beauty and Change Conference*, Turin, Italy, 2024

Internet memes for empirical aesthetics. *International Association for Empirical Aesthetics*, Palma Majorca, Spain, 2024

## Abstract

The digital era has transformed communication and expression, with internet memes emerging as a dominant form of digital communication. Despite their widespread use, the cognitive and emotional mechanisms underlying meme appreciation remain largely unexplored. This dissertation investigates how processing fluency, humor, and aesthetic emotions shape meme engagement, drawing from cognitive psychology, neuroscience, and social psychology. The study consists of three empirical investigations. The first study employs an exploratory approach to identify key predictors of meme appreciation. Factor analysis of user ratings reveals five dimensions: humor, fluency, disfluency, positive emotions, and negative emotions. The second study employs psychophysiological methods, including facial electromyography (EMG) and electrodermal activity (EDA), to examine how fluent and disfluent memes modulate emotional and arousal responses. While no significant differences in smiling (zygomatic) and frowning (corrugator) muscle activity are found, peak analyses suggest that fluent stimuli evoke faster emotional responses. Disfluent stimuli trigger higher skin conductance responses, indicating increased cognitive effort and arousal. The third study utilizes eye-tracking technology to analyze visual attention patterns in meme perception. Findings reveal that disfluent memes elicit shorter fixations with increased saccades, suggesting an exploratory attention mode, whereas fluent memes have longer fixations with fewer saccades, indicative of an exploitative processing style. Mooney images are used in Study 2, Study 3,and  Study 4to compare meme perception with other ambiguous stimuli, highlighting how fluency and ambiguity interact in digital media. This dissertation advances theoretical and practical understanding of digital aesthetics, demonstrating that meme appreciation is shaped by both cognitive ease and controlled elaboration.

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# Chapter 1

# Introduction

## 1.1 Background

Information is a foundational element of life, essential for the survival, adaptation, and evolution of all living systems. From the molecular level, where genetic information guides biological processes, to the cognitive level, where sensory and social information shapes behavior and decision-making, information underpins the mechanisms of life itself. Information facilitates communication, learning, and adaptation, enabling organisms to navigate their environments and interact with one another. The efficiency with which organisms process information often dictates their ability to thrive, as rapid and accurate interpretation of stimuli can mean the difference between survival and failure.

In humans, this efficiency is deeply tied to processing fluency, a psychological mechanism that signals the ease with which information is perceived, understood, and integrated. Fluency operates at both perceptual and conceptual levels: perceptual fluency refers to the ease of processing sensory input (e.g., visual clarity), while conceptual fluency involves the ease of understanding meaning or context (Reber et al., 2004). Processing fluency has been extensively studied as a mechanism that governs cognitive and emotional responses to stimuli. Stimuli that are easier to process tend to evoke positive emotional responses and are judged as more aesthetically pleasing, comprehensible, and even truthful (Reber et al., 2004; Winkielman et al., 2003). However, fluency is not a universal predictor of preference. A competing body of research suggests that certain forms of disfluency—whether through ambiguity, perceptual distortion, or cognitive challenge—can actually enhance engagement, interest, and memorability (Muth & Carbon, 2013). These perspectives highlight a broader debate in empirical aesthetics: while fluency theories emphasize ease as a driver of preference, learning-based accounts argue that effortful processing can create deeper cognitive rewards. Learning-based theories suggest that aesthetic preferences develop over time, with individuals becoming attuned to complex or initially challenging stimuli through repeated exposure and familiarity (Vessel et al., 2012; Graf & Landwehr, 2015).

The tools humans create to communicate have profoundly shaped how easily we generate and process information. From oral traditions to printing presses, technological advancements have expanded both the volume and complexity of information exchange. The computer represents the most powerful of these tools, facilitating the rapid production, modification, and dissemination of information at an unprecedented scale. Within this digital landscape, internet memes have emerged as a defining cultural phenomenon. Due to their constantly evolving nature, internet memes are hard to precisely define. However, media theories have characterized memes as digital artifacts that arise from a participatory media culture—a dynamic ecosystem where technological affordances encourage users to be both producers and consumers of media (Wiggins & Bowers, 2015). Internet memes are usually, but not always, humorous combinations of relevant texts and images. They differ from most aesthetic stimuli because of their ease of production with remixed but recognizable motifs and their rapid dispersion. They are created, shared, and transformed on a large scale in ways that reflect the evolving nature of digital communication, embedding them deeply into modern discourse (Shifman, 2013).

Internet memes exemplify the fundamental role of processing fluency in shaping how information is perceived, understood, and shared. Their effectiveness as digital artifacts is largely driven by their ability to capitalize on both perceptual and conceptual fluency. Perceptually, memes often adhere to familiar visual formats—recurring image templates, consistent text placement, and recognizable stylistic conventions—that streamline cognitive processing and enhance immediate recognition. Conceptually, they draw from shared cultural knowledge, referencing popular media, linguistic trends, or social norms, which allows for effortless comprehension with minimal cognitive effort. This familiarity not only makes memes easier to process but also reinforces their appeal, as fluency has been shown to increase positive affect and perceived truthfulness.

Yet, the appeal of memes is not solely rooted in fluency. Elements of ambiguity, incongruity, or moderate disfluency also play a pivotal role in their likability. Ambiguous stimuli, which lack immediate clarity or meaning, often require additional cognitive effort to resolve. Indeed, humor processing relies on the resolution of incongruities, where the brain reconciles unexpected or contradictory elements to create a sense of surprise or amusement (Suls, 1972). The relationship between ambiguity and resolution is particularly relevant in the context of internet memes, where disfluency, whether perceptual (e.g., distorted images) or conceptual (e.g., unexpected punchlines), could heighten humor, curiosity, and interest (Bekinschtein et. al, 2011, Yus, 2021).

This dynamic highlights a broader debate in empirical aesthetics, where the relationship between fluency and disfluency remains a central topic of discussion. Just as fluency theories suggest ease enhances aesthetic preference, learning-based accounts argue that effortful processing can lead to greater cognitive rewards. Memes, as rapidly evolving digital expressions, exist along this continuum, fluctuating between immediate fluency and interpretive challenge. By studying memes through the lens of processing fluency, we gain insight into how digital formats shape cognitive and affective responses, raising broader questions about the extent to which ease of processing information is a fundamental driver of engagement and aesthetic appreciation.

### 1.2 Research Objectives

The primary objective of this research is to investigate how processing fluency influences cognitive and emotional responses to internet memes. Specifically, the study aims to:

1. Use existing literature to uncover variables that influence the appreciation of internet memes.

2. Explore the differences in the emotional processing of fluent and disfluent memes compared to other ambiguous stimuli.
3. Investigate gaze patterns when processing perceptual and conceptual ambiguity of differing fluencies.

**1.3 Thesis Outline**

The thesis is organized into three main chapters. The first chapter is an exploratory study of the cognitive, emotional, and social factors contributing to meme appreciation. We used interdisciplinary theoretical frameworks to select potential variables that could influence the liking of internet memes. Then, we ran an exploratory latent factor analysis on these measured variables to see how cognitive, emotional, and social variables combine to predict the appreciation for memes. In the second chapter, we uncover the emotional processing of fluent and disfluent ambiguous stimuli using electrodermal and electromyographic signals. In one experiment, we isolate the physiological markers of fluent and disfluent internet meme processing. In a second experiment, we include Mooney images as perceptually ambiguous stimuli. Finally, in the third chapter, we incorporated eye-tracking technology to discover the gaze patterns and allocation of visual attention in memes and Mooney images. We compare and contrast how fluency plays a role in conceptual and perceptual processing of ambiguity.

**1.4 Theoretical frameworks**

Throughout the thesis, we use several theoretical frameworks to guide hypotheses and interpretations. These frameworks include user gratification theory, incongruity-resolution theory, metaphor theory, processing fluency and the pleasure-interest model, and aesthetic emotions.

*1.4.1 User Gratification Theory*

User gratification theory in media psychology posits that people are not passive recipients of media but actively choose what they consume according to their motivations, goals, and individual characteristics (Shao, 2009). People consume media, including internet memes, to meet specific needs like entertainment, social interaction, and personal identity. Then, they evaluate whether it has sufficiently met their needs and adjust their consumption accordingly. Individual differences play a key role in user gratification theory since differences in needs result in differences in evaluation and consumption behavior. One of the primary reasons people engage with internet memes seems to be their ability to provide entertainment. Unlike other digital content like news articles or personal posts, internet memes offer quick and accessible humor that allows individuals to momentarily escape reality and immerse themselves in a shared, often lighthearted, digital experience.

Beyond entertainment, memes also serve as markers of social identity, connecting individuals who share similar knowledge and tastes (Kuipers, 2009). From benign identities like donor-conceived offspring (Newton et al., 2022) to far-right groups around the world (Greene, 2019; Hakokõngäs et al., 2020; Moreno-Almeida & Gerbaudo, 2021), the understanding and appreciation of internet memes is a symbol of belonging. Ironically, this belongingness arises from exclusion. For instance, on platforms like 4chan, memes serve as cultural capital, distinguishing insiders from outsiders based on their familiarity with subcultural norms (Nissenbaum & Shifman 2017). Insider knowledge reinforces a sense of belonging, using humor and exclusivity to elicit a sense of shared distinctiveness (Brewer, 1991; Leonardelli et al., 2010).

In addition to fulfilling the need for social identity, internet memes also facilitate social interaction through activities like sharing, liking, or creating new memes. When considering the latter, versatility and replicability become important variables to prosumers. Versatility is the expansion potential or scalability of an internet meme. In a study on the Reddit community r/MemeEconomy, Literat & van den Berg (2017) found that emerging memes that offered a greater possibility for new iterations were considered to provide more value to the users. This aligns with classical memetic theory (Dawkins,1976/2016), where replication potential, or the ease of reproduction, drives a meme's success (Knobel & Lankshear, 2007).

User gratification theory offers several possible variables that influence the appreciation of internet memes. First, as active participants of media consumption, users are constantly evaluating whether an instance of media is meeting their expectations. Memes that provide *humor* or *amusement* satisfy a need for entertainment and escapism that should lead to a greater appreciation. Next, internet memes that bring attention to a user's social identity by using *exclusivity* should also be considered better than those that appeal to a general audience. Finally, internet memes high in *replicability* offer users more versatility in the way users can interact with media and the online community in general.

### *1.4.2 Incongruity Resolution Theory*

As user gratification theory suggests, humor serves as one of the primary motivations for meme consumption. One of the dominant theoretical frameworks of humor is incongruity-resolution, which states that humor is a two-step cognitive process (Suls, 1972). First, incongruity, or a violation of expectations is detected. Then, using cues and an adequate cognitive restructuring, it is resolved. Memes often create incongruity by juxtaposing texts and images in surprising yet meaningful ways (Dynel, 2016). Research on a corpus of 150 multimodal internet memes found that nearly 40% of the memes leveraged incongruity that arises from a clash between the text and the image and less than 9% did not contain any form of incongruity (Yus, 2021). This finding highlights the importance of *incongruity* and *modality* (visual, text, and multimodal) in internet meme humor.

### *1.4.3 Metaphor Theory*

Because of their incongruous multimodal nature, another popular framework for analyzing internet memes is that of a visual metaphor (Huntington, 2013; Refaie, 2003; van Mulken et al., 2014). A metaphor is a figure of speech that describes a target domain using the conceptual attributes of a source domain.

Typically, internet memes use an image as the source domain and text as the target domain (see Figure 1.1). The strength of this relationship or the degree to which the source domain captures important features of the target domain is called *aptness* (Chiappe et al., 2003; Tourangeau & Sternberg, 1981). Aptness has previously been shown to increase ratings of humor and comprehensibility of internet memes (Wong & Holyoak, 2021) and could be an important variable to consider when evaluating the appeal of internet memes.


***Figure 1.1***: *An example of visual metaphors in an internet meme (Source: Reddit). In this example, the source domain is the TV show SpongeBob, and the target domain is the experience of being at the dentist. The meme makes a relationship between one scene in SpongeBob and a common experience of a dentist asking questions while cleaning a patient.*

*1.4.4 Pleasure-Interest Theory Model of Fluency*

While previous studies have found that aptness enhances the humor of memes, subjective ratings of aptness have been shown to be affected by processing fluency (Thibodeau & Durgin, 2011). Fluency is a hedonically marked metacognitive signal of information processing ease (Winkielman et al., 2003). Stimuli with greater fluency evoke positive affect and increase aesthetic judgments just because they are easy to process (Reber et al., 2004). Two central elements of fluency are perceived or actual increased *level of understanding* (Belke et al., 2010; Miele & Molden, 2010) and faster *speeds of information processing* (Reber et al., 2004). Another variable related to fluency is *prototypicality, which refers to* how well an exemplar represents its class or category (see Rosch, 1973). Prototypical stimuli are processed with more fluency and judged to be better liked than non-prototypical stimuli (Winkielman et al., 2006). Increases in fluency are also characterized by an increased perception of truth or *truthiness* (Newman et al., 2012; Reber & Schwarz, 1999).

The Pleasure-Interest Model (Graf & Landwehr, 2015) provides a framework to understand how the perceived simplicity or complexity of a meme can either enhance or detract appreciation. When confronted with a stimulus, people compare their experienced fluency to the expected fluency. If there is a positive discrepancy between expected fluency and experienced fluency – that is, experienced fluency is higher than expected fluency – then there is a pleasant effect of fluency. But, if there is a negative discrepancy between expected and experienced fluency, this leads to an unpleasantness caused by the disfluency. These pleasant and unpleasant effects arise from an automatic information processing system that attributes the fluency discrepancy and the resulting positive or negative affect to the stimuli (Graf & Landwehr, 2015; Reber et al., 2004; Winkielman et al., 2003).

However, if a person is motivated by the need for cognitive stimulation, they can employ a slower controlled information processing system by investing cognitive resources, like attention and memory (Kahneman, 2003; Stanovich & West, 2000). If the initial disfluency is reduced through the cognitive elaboration process, people can feel another positive aesthetic emotion: interest. If the disfluency is never resolved, even with controlled processing, the unpleasantness turns into *confusion*. On the other hand, a person with a high need for cognitive stimulation, such as a user seeking a challenging meme, can choose to continue cognitive elaboration even if they already had a positive fluency discrepancy. But they are likely not able to meet their needs through more elaboration. Thus, their initial pleasant affect turns into *boredom*. In summary, this balance between fluency and disfluency could be important for the understanding and appreciation of internet memes.

*1.4.5 Aesthetic Emotions*

The Pleasure-Interest model highlights interest, confusion, and boredom as key emotions involved when a stimulus is disfluent. However, emotions in general seem to play an important role in the appreciation of internet memes and engagement on social media platforms overall. Researchers have found that internet videos that elicit a stronger affective response were more likely to be shared, especially if they had a positive valence (Guadagno et al., 2013). However, because of the many theories of emotions, their origins, and their functions, defining emotions becomes a difficult task. In recent decades, empirical aesthetic researchers have transitioned from arousal theories of emotion to the appraisal framework of “aesthetic emotions” (Silvia, 2005). Appraisal theory explains that two people can have different emotional reactions to the same stimulus due to differences in relevance to their goals, matches to their expectations, or other appraisal dimensions (Moors, 2020). Appraisal theory fits into the component process model of emotion (Scherer, 2005) that distinguishes five components of emotions:

1. Cognitive component that evaluates objects and events.

2. Neurophysiological component that regulates the nervous system.

3. Motivational component that prepares the organism for action.

4. Facial expression component that communicates reaction and behavioral intention.

5. Subjective feeling component that monitors the internal state of the organism.

Aesthetic emotions, then, are "full-blown discrete emotions that, for all their differences in multiple emotion components, always include an aesthetic evaluation/appreciation of the objects or events under consideration." (Menninghaus et al., 2019, p. 185). Ordinary emotions like amusement, boredom, anger, and surprise become aesthetic emotions only when they are direct predictors of a resulting aesthetic evaluation. Aesthetic emotions also encompass several key dimensions of cognitive appraisals, namely pleasantness, novelty, goal relevance, and coping potential, which play significant roles in shaping aesthetic evaluations (Menninghaus et al., 2019). For example, a balanced combination of novelty and familiarity can create appealing cognitive challenges that do not exceed the coping potential of the individual (Hekkert et al., 2003), allowing for more curiosity and excitement instead of confusion and anxiety.

The aesthetic emotions framework is useful for defining emotions, but it is not without controversy. Other researchers (Skov & Nadal, 2020) deny the separation between "ordinary emotions" and "aesthetic emotions". They claim that there is no empirical evidence to suggest that aesthetic emotions are fundamentally different, neurobiologically or physiologically, from other emotions. Their view is that emotions have evolved for survival have gone on to regulate other behaviors like appreciating art. Instead of being a different class of emotions, they are the same emotions but in an aesthetic context.

Despite the debate on whether aesthetic emotions are a special class of emotions or not, there is research that suggests the processing of emotions tends to be different when in an aesthetic context. For example, there seems to be a positivity bias in the processing of aesthetic emotions where negative emotions are not processed with the same intensity as positive emotions. Because of the distanced evaluative nature of aesthetic emotions, aesthetic negative emotions are not as salient or processed with as much granularity compared to ordinary negative emotions (Menninghaus et al., 2017). Furthermore, aesthetic emotions have an increased tolerance to which greater levels of emotional intensity can be enjoyed, compared to ordinary emotions, even when arousal is high. This could be due to lack of threat to one's safety during an aesthetic experience. The situational context of aesthetic experiences allows for attention to be directed away from the motivational component and towards the subjective feeling component (Menninghaus et al., 2019). For example, the ordinary emotion *fear* includes the motivational tendency to escape the source of the emotion. But fear in an aesthetic context (e.g., watching a horror movie at home) can be enjoyed with greater intensities. Therefore, the intensity of positive and negative aesthetic emotions, novelty, and coping potential could be significant emotional factors in the appreciation of internet memes.

# Chapter 2

# Ingredients for a Good Meme: Cognitive, Emotional, and Social Factors of Internet Meme Appreciation

## 2.1 Introduction

According to Statistica, 5.17 billion people or 63.7% of the world's population use social media every day (Petrosyan, 2024). In Europe and North America, Instagram is especially popular with young adults aged 18-29 with 71% being active users of the platform (Anderson, 2021). More than one million of these daily interactions on Instagram involve the sharing of internet memes (Instagram, 2020). But what drives online users to create and share these artifacts? A YPulse survey found that 74% of individuals share memes to make others laugh, 53% use them as responses, 35% send them as coded messages to those who will "get it," and 28% utilize them when words fail to express their feelings (YPulse, 2019). Memes have a multimodal grammar, combining texts and images to create unique and exclusive narratives (Dancygier & Vandelanotte, 2017; Geeraerts & Zenner, 2018). Images are often recycled leading to the emergence of meme families with distinct recurring features, or quiddities (Segev et al., 2015). While some memes focus on simple humor, others tackle serious issues such as political participation, environmental communication, and mental health, highlighting that memes should not be equated solely with jokes. (Akram et al., 2020; Huntington, 2016; Milner, 2013; Ross & Rivers, 2017, 2019; Zhang & Pinto, 2021).

Despite their prevalence and growing cultural and financial impact, academia is just catching up to these fast-paced digital phenomena. Although prior research has focused on what memes are and how they spread, it remains poorly understood why people find them so appealing in the first place. The research objective of this thesis is to uncover why humans like memes. This first study is an exploratory investigation into the appreciation of internet memes. It addresses why internet memes are appealing to people by focusing on cognitive, emotional, and social factors. We draw upon the theoretical frameworks to uncover insights into how individuals engage with memes. User gratification theory will highlight how users actively seek content that meets their needs, while incongruity-resolution explains the humor that arises from unexpected violations. Additionally, metaphor theory examines the role of aptness in visual and textual elements for meaning and processing fluency explores how ease of understanding influences emotional responses. Finally, aesthetic emotions will show how evaluative dimensions shape emotional responses and overall appreciation. This study serves as a starting point, providing insights into cognitive psychology and providing a validated database of stimuli that inform the subsequent research presented in this thesis.

### *2.1.1 Study Objectives*

The primary objective of this study is to uncover the cognitive, emotional, and social factors that contribute to the appreciation of internet memes. We use largely exploratory analyses to give a data-driven answer. Though supported by our theoretical frameworks, we hypothesized that variables like positive emotions, humor, aptness, prototypicality, truthiness, level of understanding, and speed of processing would have a significant positive effect on overall liking. We also predicted that negative emotions, specifically confusion and frustration, would have a significant negative effect on overall liking.

## 2.2 Methods

### *2.2.1 Preregistration*

Prior to data collection, we pre-registered our variables, design, and sampling plan in an OSF Project repository (Ayele, 2024).

### *2.2.2 Participants*

Participants (N= 1,157) were recruited online with an anonymous link distributed on several social media platforms like Facebook, Reddit, and TikTok from April to May 2022. An anonymous survey link was posted in several Facebook and Reddit groups and organic (unpaid) TikTok video campaigns were posted to recruit online participants. Participation in the study was completely voluntary and not paid. There were no sample restrictions other than being over the age of 18. Four participants were removed for reporting their age under this limit for a final sample size of N = 1,153. Participants provided informed consent at the beginning of the survey. All study procedures were conducted in accordance with the Declaration of Helsinki and approved by the Comitato etico congiunto per la ricerca della Scuola Superiore Sant'Anna e Scuola Normale Superiore (approval number 39/2022).

*2.2.3 Demographics*

From April 2022 to May 10, 2022, a demographics survey was placed at the end to collect age, gender, native English speakers, social media activity, age of exposure to internet memes, meme knowledgeability, and attitude towards memes. However, many participants did not complete this part due to survey dropout. On May 10th, we moved the demographics survey to the beginning of the experiment. During this period, N= 78 new participants were collected. This resulted in a reasonable sub-sample (N = 408) with complete demographic information. Of the participants who provided demographic information, 59.3% were female, 23.5% were male, 15.0% were non-binary, and 2.5% were undisclosed. Their ages ranged from 18 to 63 ($M = 37.51$, $MDN = 34$, $SD = 15.85$). While 51.2% of the participants reported the United States as their country of origin (51.2%), the other 48.8% resided in 40 other unique countries, including the United Kingdom (9.8%), Germany (6.4%), and Italy (4.4%). Most participants (71.7%) reported that they were native English speakers.

*2.2.4 Stimuli*

We collected 300 user-generated internet memes between December 2021 and March 2022 from a variety of sources like Reddit, Instagram, Facebook, Twitter, and ImgFlip. The sample contained 200 multimodal image macros and 100 unimodal exemplars. Half of the multimodal sample contained four unique instances of 25 identifiable repeated meme template images (e.g., "Change My Mind," "Bad Luck Brian," "Surprised Pikachu", Figure 2.1) (Segev et al., 2015). We call these family memes. The other half were singular instances of texts superimposed on images. We call these memes non-family memes. Because of a coding error, one non-family meme did not have emotional intensity data and was excluded from the analysis. We manipulated the variable *modality* by including 50 text-only memes and 50 visual-only memes to test the significance of modality on meme appreciation.


**Figure 2.1:** One example of a family memes is the “I bet he’s thinking about other women” template.

*2.2.5 Procedure*

The study was administered on Qualtrics. Participants were asked to rate up to 15 randomly selected internet memes from our collection. Those over the age of 18 who completed a minimum of one internet meme rating were included in the analysis. All 300 memes received a minimum of 15 ratings, a median of 27 ratings, and a maximum of 41 ratings. In total, we had N = 8,075 observations.

*2.2.6 Measures*

Participants were asked to evaluate several dimensions (Table 2.1). To gather a generalized measure of overall liking, participants were asked to provide ratings using a 5-star scale ranging from 0.5 to five stars. Participants used visual-analog scales to rate a total of nine cognitive features selected from the literature on fluency, metaphor, and humor theory. Participants were also asked to indicate whether they would 'like' or 'share' the meme on their social media. As the analyses with likability and shareability yielded results that led to the same conclusions, we report only the results for overall liking. Participants reported their emotional state(s) elicited by each meme using a selection of 16 discrete emotional categories: adoration, amusement, anger, boredom, compassion, confusion, disgust, embarrassment, fear, frustration, nostalgia, relief, sadness, satisfaction, surprise, and tenderness, balanced for the positive and negative valence (Scherer, 2005). Each word was accompanied by a signifying emoji, similar to reactions that are found on social media networks (Jaeger et al., 2018; Tian et al., 2017).

Finally, participants were asked to provide their interpretation of the meme using a free text entry. Two independent coders manually coded the interpretations of 20 randomly sampled internet memes (n = 380 participants, 520 observations) to ascertain the accuracy of the participants' interpretation. The coders were given references to the meanings of the memes and instructed to evaluate the written interpretation of participants as 0 for an invalid response, 1 for a false understanding, 2 for a true but incomplete understanding, or 3 for a true and complete understanding. We found that the greater scores of interpretation accuracy predicted the participants' self-reported 'level of understanding' in both Coder 1 ($b = 0.87$, $F(1, 365) = 32.04$, $p < 0.001$) and Coder 2 ($b = 0.89$, $F(1, 365) = 29.29$, $p < 0.001$), providing support that participants were quite accurate in their self-report of understanding the memes.

| Variable | Instruction | Measurement |
|---|---|---|
| Overall liking | Please rate this meme | 5-points star scale, including half-steps |
| Humor | This image is 1= "not funny at all" 10 = "extremely funny" | Visual-analogue scale from 1-10 |
| Incongruity | The relationship of the concepts presented is (1 = very predictable, 10 = very unpredictable) | Visual-analogue scale from 1-10 |
| Level of understanding | My level of understanding of this image is 1 = "very low"" 10 = "very high" | Visual-analogue scale from 1-10 |
| Speed of processing | My understanding of this image was 1 = "very slow to process" 10 = "very fast to process" | Visual-analogue scale from 1-10 |
| Prototypicality | This is 1= "a very bad representation of internet memes" 10 = "a very good representation of internet memes" | Visual-analogue scale from 1-10 |
| Truthiness | The feeling of truth in this meme is 1 = "not true at all" 10 = "extremely true" | Visual-analogue scale from 1-10 |

| | | |
|---|---|---|
| Aptness | The relationship of the concepts presented is 1= "not fitting at all" 10 = "extremely fitting" | Visual-analogue scale from 1-10 |
| Exclusivity | The meaning of this meme is 1 = "very accessible to a general internet audience" 10 = "very inaccessible to a general internet audience" | Visual-analogue scale from 1-10 |
| Replicability | This meme would be 1 = "very hard to recreate", 10 = "very easy to recreate" | Visual-analogue scale from 1-10 |
| Likeability | I would ‘Like” this on social media | Likert scale from 1 (definitely not) to 5 (definitely yes) |
| Shareability | I would “Share” this on social media | Likert scale from 1 (not) to 5 (definitely yes) |
| Emotions | How does this make you feel? | Visual-analogue scale from 1-10 of 16 emotional categories |

***Table 2.1:*** *A complete list of all the measured variables*

### *2.2.7 Data Analysis*

#### 2.2.7.1 Exploratory Graph and Factor Analysis.

To build a model that can reliably predict the ratings of new internet memes, we first split the data (N = 8075 observations) into 80% training and 20% testing data. Then, we ran an exploratory factor analysis on the training dataset to find the latent factors in the measured cognitive and emotional variables. One meme with missing emotional ratings was removed for this analysis.

Before conducting the exploratory factor analysis, we ran several tests to check the factorability of our data (Ferguson & Cox, 1993). First, we calculated the determinant of the correlation between the raw cognitive and emotional variables. Our determinant was 0.0003, well above the recommended minimum of 0.00001. Then, we performed a Kaiser-Meyer-Olkin Test (KMO) for sample adequacy (MSA) and found a total MSA = 0.85, indicating an adequate sampling for factor analysis. Finally, Bartlett's Test of Sphericity was performed to check if there were any significant relationships to be found in the measured variables. Our test found a p-value $< 0.001$, showing that factor analysis can reveal latent relationships in the data.

To determine the number of latent factors in our data, we used the EGA package in R to conduct an exploratory graph analysis. We implemented a graphical lasso model (Jung et al., 2014) with the Louvain clustering algorithm (Blondel et al., 2008). Since the raw data included high correlations, an exploratory graph analysis offered a better approximation of the number of factors than traditional methods (Golino & Epskamp, 2017). Then, we conducted the exploratory factor analysis with Promax rotation using the *factanal* package in R. This procedure determined that the best fit for our data were 5 latent factors.

#### 2.2.7.2 Cross-Validated Regression and Prediction.

To understand which of the factors were the strongest predictors of overall liking, we trained a 10-fold cross-validated linear regression model using the *caret* package in R. The dataset was divided into ten equal parts and the model was trained on nine folds while testing it on the remaining fold. This process was repeated ten times, with each fold serving as the test set once, and the results were averaged for a more reliable performance estimate. We used the factor scores from the exploratory factor analysis as predictors and the overall liking as the dependent variable. Then, we factorized the test dataset in the same manner as the training data. To check if our model was accurate, we used the resulting regression equation to predict the overall liking of the remaining 20% test data.

2.2.7.3 Stimulus Type Influences on Ratings and Factor Loadings.

Next, we wanted to ascertain if stimulus type influenced the overall liking of memes and the results of the exploratory factor analysis. To estimate this, we fit six linear mixed-effects models ($\alpha = 0.01$). Linear mixed-effects models were used to control for the inherent random effects of stimulus and participant ID in our data. The fixed effect in our model was one categorical variable with four non-ordinal levels containing the modality of the meme (family, non-family, visual-only, text-only). Our dependent variables were overall liking and the other factor scores. One example structure of our models is as follows:

```
Model1 <- lmer(Fluency ~ Type + (1 | Participant) + (1 | Meme))
```

Post-hoc tests on the models were conducted using the *emmeans* package in R. We used an alpha level of 0.05 to make inferences about pairwise estimated marginal mean contrasts in the post-hoc tests and controlled for multiple comparisons using Tukey-HSD. All data and code are publicly available on the OSF Project repository (Ayele, 2024).

## 2.3 Results

### *2.3.1 Exploratory Graph and Factor Analysis*

From the exploratory graph analysis (EGA) and the exploratory factor analysis (EFA), we found five latent factors in our data (Figure 2.2) and which measure loaded into each of the five factors (Table 2.2). As seen in Table 2.2, Factor 1 was positively loaded with level of understanding, speed of processing, aptness, truthiness, prototypicality, replicability, and negatively loaded with confusion. Factor 2 was positively loaded with humor and amusement, and negatively loaded with boredom. Factor 3 was positively loaded with anger, disgust, embarrassment, fear, frustration, and sadness. Factor 4 was positively loaded with adoration, compassion, nostalgia, relief, satisfaction, and tenderness. Finally, factor 5 was positively loaded with incongruity, exclusivity, replicability, and confusion. Notably, surprise did not significantly load into any of the factors. Though this was an exploratory factor analysis, and we did not expect these factors beforehand, we labeled the factors "fluency," "humor," "negative emotion," "positive emotion," and "disfluency" for readability. To justify the naming of opposing variables like "positive emotions" and "negative emotions" or "fluency" and "disfluency," we conducted Pearson correlations over the EFA scores. The correlations were significant and negative in both cases (positive and negative emotions: $r = -0.36$, $p < 0.001$; fluency and disfluency: $r = -0.31$, $p < 0.001$). For other factor correlations, see Appendix A.

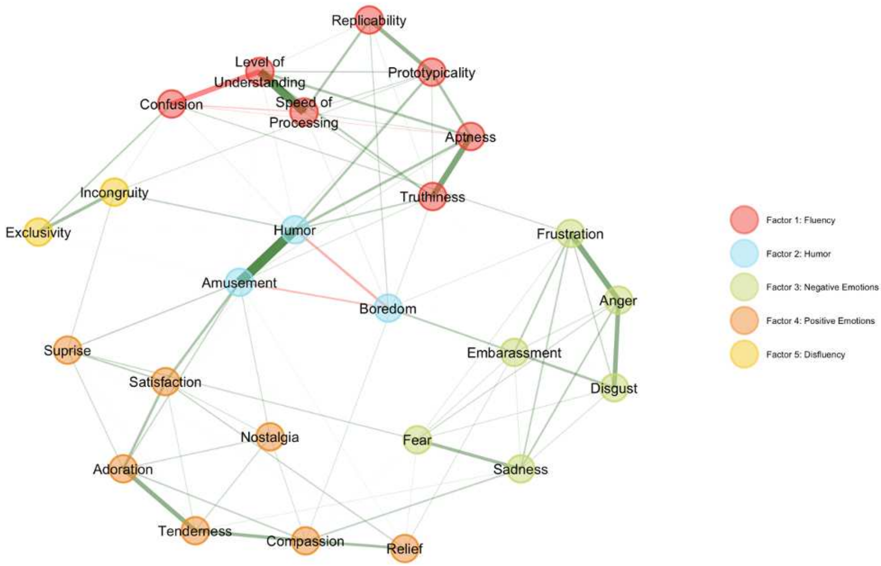


**Figure 2.2:** Exploratory graph analysis of the relationships between cognitive and emotional ratings

| Item | Fluency | Humor | Negative Emotion | Positive Emotion | Disfluency |
|---|---|---|---|---|---|
| Humor | | 0.832 | | | |
| Aptness | 0.594 | | | | |
| Incongruity | | | | | 0.339 |
| Prototypicality | 0.493 | | | | |
| Truthiness | 0.558 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Level of Understanding | 0.964 | | | | |
| Speed of Processing | 0.915 | | | | |
| Exclusivity | | | | | 0.406 |
| Replicability | 0.526 | | | | 0.322 |
| Adoration | | | | 0.608 | |
| Amusement | | 0.823 | | | |
| Anger | | | 0.76 | | |
| Boredom | | -0.581 | | | |
| Compassion | | | | 0.544 | |
| Confusion | -0.712 | | | | 0.526 |
| Disgust | | | 0.62 | | |
| Embarrassment | | | 0.416 | | |
| Fear | | | 0.375 | | |
| Frustration | | | 0.662 | | |

| | | | | | |
|---|---|---|---|---|---|
| Nostalgia | | | | 0.341 | |
| Relief | | | | 0.329 | |
| Sadness | | | 0.415 | | |
| Satisfaction | | | | 0.346 | |
| Surprise | | | | | |
| Tenderness | | | | 0.744 | |

***Table 2.2:*** *Exploratory factor loadings and uniqueness for cognitive and emotional ingredients, shown for factor loadings above 0.30 or below -0.30.*

### *2.3.2 Cross-Validated Regression Model and Prediction of Overall liking*

Next, we wanted to understand which of the five factors was the best predictor of the overall liking of internet memes. The cross-validated regression results (Table 2.3) show that the humor factor was the strongest predictor of overall liking in our model ($b = 1.20$, $p < 0.01$). Fluency ($b = 0.74$, $p < 0.01$), positive emotions ($b = 0.47$, $p < 0.01$), and disfluency ($b = 0.41$, $p < 0.01$) had significant positive effects on the overall liking. By contrast, negative emotions had significant negative effects ($b = -0.25$, $p < 0.01$) on internet meme ratings. The model had an adjusted $R^2 = 0.74$. This means that all five of the latent factors had significant but varying roles in the appreciation of internet memes. When we use this model to predict the remaining 20% of test internet memes, we find that the model is accurate with a mean absolute error (MAE) = 0.54. It can predict the ratings of new internet memes with about a half-point margin of error.

| Predictor | *b* | *b* 95% CI [LL, UL] | *beta* | *beta* 95% CI [LL, UL] | $sr^2$ | $sr^2$ 95% CI [LL, UL] | *r* | Fit |
|---|---|---|---|---|---|---|---|---|
| (Intercept) | 2.84** | [2.82, 2.86] | | | | | | |
| Fluency | 0.74** | [0.72, 0.75] | 0.58 | [0.56, 0.59] | .26 | [.25, .28] | .22** | |
| Humor | 1.20** | [1.18, 1.22] | 0.97 | [0.96, 0.99] | .69 | [.68, .70] | .63** | |
| Negative Emotions | -0.25** | [-0.27, -0.23] | -0.17 | [-0.18, -0.16] | .02 | [.02, .03] | -.01 | |
| Positive Emotions | 0.47** | [0.45, 0.49] | 0.33 | [0.32, 0.35] | .09 | [.08, .09] | .01 | |
| Disfluency | 0.41** | [0.38, 0.43] | 0.25 | [0.23, 0.26] | .05 | [.05, .06] | -.02* | |
| | | | | | | | | $R^2$ = |

| |
|---|
| .740<br>** |
| 95%<br>CI<br>[.73,<br>.75] |

***Table 2.3**: Cross-Validated Regression Results using Overall liking as the dependent variable. Note.* A significant *b*-weight indicates the beta-weight and semi-partial correlation are also significant. *b* represents unstandardized regression weights. *beta* indicates the standardized regression weights. $sr^2$ represents the semi-partial correlation squared. *r* represents the zero-order correlation. *LL* and *UL* indicate the lower and upper limits of a confidence interval, respectively. * Indicates $p < .05$. ** indicates $p < .01$.

*2.3.3 Stimulus Modality Effects on Overall liking and Factor Loadings*

We used linear mixed-effects models to understand whether the type of stimuli (family, non-family, visual-only, or text-only memes) influenced the overall liking or factor scores (see Appendix Table A.2 for LMM results). The results showed that stimulus modality did significantly influence overall liking and some factor scores (Table 2.4). For the overall liking, we found that visual-only memes had significantly lower overall liking compared to family memes, non-family memes, and text-only memes. This means that visual-only memes were the least appreciated type of internet meme in our collection. Family memes also had significantly lower overall liking compared to non-family memes. Of the selection of multimodal memes, participants appreciated the more novel non-family memes compared to conventional family memes. Similarly, we found that family memes were also considered significantly less humorous than non-family memes, text-only memes, and visual-only memes.

In the loadings of the fluency factor, we found that family memes were instead rated as more fluent than non-family memes. We also found that visual-only memes had significantly lower fluency scores than family memes, non-family memes, and text-only memes. This suggests that visual-only memes were the least fluent type of meme. We also found this pattern in the disfluency scores. Visual-only memes were rated as more disfluent than family memes, non-family memes, and text-only memes. Moreover, we found that text-only memes were significantly less disfluent than family memes and non-family memes. Therefore, text-only memes were the least disfluent type of stimuli in our collection. We did not find significant differences in disfluency between family and non-family memes.

When considering negative emotions, we only found that family memes and visual-only memes elicited greater negative emotions compared to non-family memes. Inversely, family memes elicited less intense positive emotions than non-family memes and text-only memes. Visual memes also elicited less intense positive emotions than non-family memes. In summary, family memes and visual-only memes elicited greater negative emotions and less positive emotions than other types of memes.

**Dependent Variable: Overall liking**

| (I) Type | (J) Type | Mean Difference (I – J) | Std. Error | z. ratio | Sig |
|---|---|---|---|---|---|
| Family | Non-Family | -0.213 | 0.074 | -2.891 | 0.020 |
| Family | Text | -0.168 | 0.090 | -1.859 | 0.246 |
| Family | Visual | 0.294 | 0.090 | 3.251 | 0.006 |

| | | | | | |
|---|---|---|---|---|---|
| Non-Family | Text | 0.046 | 0.090 | 0.507 | 0.957 |
| Non-Family | Visual | 0.507 | 0.090 | 5.611 | <0.001 |
| Text | Visual | 0.461 | 0.104 | 4.431 | <0.001 |

**Dependent Variable: Humor**

| (I) Type | (J) Type | Mean Difference (I – J) | Std. Error | z. ratio | Sig |
|---|---|---|---|---|---|
| Family | Non-Family | -0.251 | 0.061 | -4.127 | <0.001 |
| Family | Text | -0.295 | 0.074 | -3.978 | <0.001 |
| Family | Visual | -0.237 | 0.074 | -3.190 | 0.008 |
| Non-Family | Text | -0.045 | 0.074 | -0.601 | 0.932 |
| Non-Family | Visual | 0.013 | 0.074 | 0.180 | 0.998 |
| Text | Visual | 0.058 | 0.086 | 0.676 | 0.906 |

**Dependent Variable: Fluency**

| (I) Type | (J) Type | Mean Difference (I – J) | Std. Error | z. ratio | Sig |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Family | Non-Family | 0.342 | 0.074 | 4.621 | <0.001 |
| Family | Text | 0.197 | 0.091 | 2.177 | 0.130 |
| Family | Visual | 0.924 | 0.091 | 10.186 | <0.001 |
| Non-Family | Text | -0.145 | 0.091 | -1.601 | 0.378 |
| Non-Family | Visual | 0.582 | 0.091 | 6.413 | <0.001 |
| Text | Visual | 0.727 | 0.105 | 6.945 | <0.001 |

**Dependent Variable: Disfluency**

| (I) Type | (J) Type | Mean Difference (I – J) | Std. Error | z. ratio | Sig |
|---|---|---|---|---|---|
| Family | Non-Family | -0.008 | 0.045 | -0.172 | 0.998 |
| Family | Text | 0.263 | 0.055 | 4.810 | <0.001 |
| Family | Visual | -0.214 | 0.055 | -3.908 | 0.001 |
| Non-Family | Text | 0.270 | 0.055 | 4.952 | <0.001 |

| | | | | | |
|---|---|---|---|---|---|
| Non-Family | Visual | -0.206 | 0.055 | -3.768 | 0.001 |
| Text | Visual | -0.477 | 0.063 | -7.555 | <0.001 |

**Dependent Variable: Negative Emotions**

| (I) Type | (J) Type | Mean Difference (I – J) | Std. Error | z. ratio | Sig |
|---|---|---|---|---|---|
| Family | Non-Family | 0.140 | 0.045 | 3.094 | 0.011 |
| Family | Text | 0.071 | 0.055 | 1.291 | 0.569 |
| Family | Visual | -0.007 | 0.056 | -0.119 | 0.999 |
| Non-Family | Text | -0.069 | 0.055 | -1.244 | 0.599 |
| Non-Family | Visual | -0.147 | 0.056 | -2.645 | 0.041 |
| Text | Visual | -0.078 | 0.064 | -1.221 | 0.613 |

**Dependent Variable: Positive Emotions**

| (I) Type | (J) Type | Mean Difference | Std. Error | z. ratio | Sig |
|---|---|---|---|---|---|

| | | (I – J) | | | |
|---|---|---|---|---|---|
| Family | Non-Family | -0.204 | 0.044 | -4.655 | <0.001 |
| Family | Text | -0.160 | 0.053 | -2.986 | 0.015 |
| Family | Visual | -0.058 | 0.054 | -1.088 | 0.697 |
| Non-Family | Text | 0.044 | 0.053 | 0.827 | 0.842 |
| Non-Family | Visual | 0.146 | 0.054 | 2.713 | 0.034 |
| Text | Visual | 0.101 | 0.062 | 1.640 | 0.356 |

***Table 2.4:*** *Pairwise Estimated Marginal Mean Contrasts between the stimuli modalities on the overall liking and factor scores.*

## 2.4 Discussion

The present study is, to our knowledge, the first to explore the cognitive, emotional, and social factors that affect the appreciation of internet memes. Our exploratory factor analysis uncovered five key ingredients underlying the 26 measured variables. The strongest predictor of internet meme appreciation was a factor positively loaded with humor and amusement and negatively loaded with boredom. Another important ingredient was fluency that had a substantial positive effect on internet meme ratings. A disfluency factor also increased the ratings of memes. Furthermore, a positive emotional factor with loadings like tenderness and compassion increased ratings while a negative emotional factor loaded with emotions like anger and frustration decreased them. In the following, we discuss these results in the light of the user-gratification, incongruity-resolution, metaphor, pleasure-interest, and aesthetic emotions perspectives reviewed in the introduction.

### *2.4.1 Humor, Amusement, Boredom and the Need for Entertainment*

Humor and amusement were the best predictors of internet meme appreciation. This finding is not surprising considering user gratification theory proposes that entertainment is an important need users seek to gratify with media. Humor is a series of cognitive shifts and expectation violations done in a playful and safe manner (Morreall, 2009). The subjective feeling and intensity of amusement is an internal signal (Scherer, 2005) of how stimulating or pleasurable this process evoked by a stimulus was. Internet memes, especially, are a genre of digital media that are created and consumed with an expectation to provide a rewarding experience (Leiser, 2022; Wiggins & Bowers, 2015). Memes that meet this expectation are rated better and considered more humorous and amusing while memes that fall short of expectations are rated as more boring. Boredom is also a signal of overlearning where needs for cognitive elaboration are not met (Graf & Landwehr, 2015). In general, judgements of humor, amusement, and boredom are the most impactful cognitive and emotional ingredients that predict appreciation for internet memes.

### *2.4.2 Boundary-Marking Incongruity*

Incongruity, exclusivity, confusion, and replicability were key ingredients in the disfluency factor that positively predicted meme ratings. Internet memes that violated expectations unpredictably tended to evoke confusion. However, when resolved, memes increase a sense of belongingness by forming a symbolic social boundary around the group or community that understands it (Kuipers, 2009). This gratifies the need for personal identity and shared distinctiveness (Brewer, 1979; Leonardelli et al., 2010). Replicability, or the perceived ease of reproduction, was also an ingredient in this factor. The replicability of a meme offers prosumers–the producers and consumers of media– an additional way to interact online. In creating a new version of the meme, prosumers' creations have the chance to gain likes, comments, and even go viral. The replicability of the meme facilitates this method of social interaction, another need from user gratification theory. These findings echo previous research that the appraisal of internet meme value relates to its relationship to the mainstream internet culture and the versatility of the meme (Literat & van den Berg, 2017).

*2.4.3 Metaphorical Aptness*

Our results support the finding that metaphorical aptness does influence the ratings of internet memes (Wong & Holyoak, 2021). However, we found that aptness was not a standalone predictor of meme appreciation. Instead, we found more evidence that subjective ratings of aptness are connected to processing fluency variables like level of understanding and truthiness (Thibodeau & Durgin, 2011). This further elaborates the findings of Wong & Holyoak that judgments of meme aptness are mediated by relatability or possibility to understand based on previous experiences. Relatable memes should be more fluent compared to non-relatable memes since they do not require extensive cognitive elaboration and feel truer to life. Therefore, aptness could be conceptualized in terms of fluency.

*2.4.4 Balance of Fluency and Disfluency*

Like other visual stimuli, internet memes are subject to the influence of processing fluency (Reber et. al 2004). Memes that were reported to be understood better, processed faster, were more prototypical, easier to replicate, with a greater sense of truth had increased overall liking. But the dual nature of confusion in the fluency and disfluency factors counters the idea that processing fluency has a linear relationship with overall liking of internet memes. Instead, the results provide more evidence for the hierarchical pleasure-interest model of aesthetic liking (Graf & Landwehr, 2015). If the processing of a meme led to a positive fluency discrepancy (stimulus more fluent than expected) and participants did not have a need for more elaboration, they were subject to the pleasant effects of processing fluency. However, if they had a negative fluency discrepancy (stimulus less fluent than expected), they felt confused. Disfluency can be resolved with cognitive elaboration and turned to a pleasurable affect that increases internet meme ratings. But, if the disfluency of a meme is never resolved, it remains as confusion that obstructs comprehension and lowers aesthetic ratings.

*2.4.5 Positive and Negative Aesthetic Emotions*

Similar to the PIA model, our results showed that amusement, boredom, and confusion were the key aesthetic emotions behind the appreciation of internet memes. Each of these emotions, combined with other cognitive factors, significantly predict the overall liking of internet memes. But in general, the variety of emotional intensity also shows that internet memes can elicit a diverse set of aesthetic emotions that predict appreciation. We found that positive emotions were stronger predictors of overall liking than negative emotions. This corroborates previous findings of the positivity bias in the processing of aesthetic emotions. Positive emotions, such as tenderness, compassion, and satisfaction, exhibited a greater asymmetric increase in overall liking compared to negative emotions, including anger, frustration, and disgust, which produced a relatively smaller decrease in the ratings. However, this could also be due to the fact that memes are typically designed to be entertaining and evoke positive emotions. This could also lead to an emotional asymmetry as the stimulus set is biased towards positive emotions. Remarkably, the only emotion that did not significantly load into any of the factors was surprise. Generally, surprise was not elicited as intensely as other emotions like satisfaction and nostalgia. Surprise could also have a mixed role between positive and negative emotions that could not be distinguished by our exploratory model. Indeed, some studies found that surprises may be pleasurable (Valenzuela et al., 2010), slightly negative (Noordewier & Breugelmans, 2013) or neutral (see Reisenzein & Meyer, 2009). However, in another study on ugly-cute visual-only memes in China, surprise did not play a significant or mediating role on the ratings of their attractiveness (Li et al., 2024). Therefore, it is likely that surprise is not an important aesthetic emotion for internet meme appreciation.

### *2.4.6 Influence of Modality*

Along with humor, multimodality is a key signifier of internet memes. However, our results show that not all multimodal memes are judged the same. We found that family memes were the most fluent (Figure 2.3a) but had the lower humor factor scores compared to all the other modalities. We reason this is because internet memes with more novel formats and structures (Figure 2.3b) have the potential to evoke greater cognitive shifts – and therefore insights and aha-experiences (see Topolinski & Reber, 2010; Wiley & Danek, 2024) – than memes from recognizable families. As family memes rely on repetitive image information, their novelty only comes from the unique pairing of text and image. However, if this pairing is not cognitively stimulating, it can easily lead to boredom. Compared to non-family memes that have both unique image information and text information, family memes have less disfluency to be resolved and, therefore, include less potential for humor and amusement. We also found that the visual-only modality was the least liked modality of internet memes. Visual-only memes were especially difficult to process, but not because of their unimodal quality. We found that text-only memes were comparable in fluency to the multimodal internet memes. Rather, unlike text-only memes, it is harder to extract a clear narrative or meaning without the guidance of linguistic elements as shown by lower fluency and higher disfluency scores for visual only memes compared to the other modalities (Figure 2.3). This finding mirrors the 'entitling art' effect, where adding elaborative titles to visual works of art like paintings and photographs changes aesthetic processing and judgment (Castellotti et al., 2023; Gerger & Leder, 2015; Leder et al., 2006). Textual elements in memes and visual art are important to grab onto necessary context needed to reduce disfluency and turn unpleasant affect into interest or amusement.


***Figure 2.3:*** *Differences in meme modality. Note: a) 'Highway Exit' family internet meme with average overall liking = 3.00, fluency score = 0.83, and humor score = -0.35; b) non-family internet meme with average overall liking = 3.53, fluency score = 0.33, and humor score = 0.68; c) visual-only meme with average overall liking = 1.76, fluency score = -2.12, and humor score = -0.08; d) text-only meme with average overall liking = 3.58, fluency score = 0.36 and humor score = 0.38 Source: Facebook, Instagram, and Twitter*

### *2.4.7 Study Implications*

This study offers several implications, especially for aesthetics and engagement in digital media. It broadens the scope of empirical aesthetics by applying its theories to a new form of creative expressions: internet memes. By examining memes as aesthetic stimuli, the study challenges conventional notions and introduces new research avenues for empirical aesthetics in the digital age. The application of established principles, such as the pleasure-interest model of fluency, to other emotional responses, like amusement, contributes to a deeper understanding of preferences for online content. This suggests that digital media could be valuable stimuli for empirical aesthetics research, offering new avenues for exploring aesthetic experiences.

This study also contributes to a deeper understanding of meme culture and its role in contemporary digital communication by revealing why some memes resonate more than others. One of the key findings relates to how fluency, which has been shown to affect perceptions of truth, plays a role in meme appreciation. As memes often carry complex social and political messages (Ross & Rivers, 2017; Zhang & Pinto, 2021), the insights provided by this research can inform digital literacy initiatives. By becoming aware of how fluency effects work, users can better identify when they might be favoring certain memes or digital content simply because it is easy to process, rather than because it carries a deeper or more truthful message. This awareness can contribute to more critical and reflective digital consumption.

Finally, as artificial intelligence (AI) generated content gains popularity, the findings of this study may influence the design and application of AI in content creation or moderation (Priyadarshini & Cotton, 2022; Yankoski et al., 2021). The dimensions of meme appreciation identified—such as humor, fluency, and emotional engagement—could inform algorithms used for content curation or moderation on social media platforms. By understanding which factors contribute to meme appreciation, AI systems could be developed to generate content that aligns with human preferences for certain types of digital stimuli. Furthermore, as AI-generated memes become a reality, the insights from this study could help refine algorithms to produce content that resonates with users in more naturalistic ways, thereby enhancing the effectiveness and relatability of AI-generated content.

*2.4.8 Limitations*

Although our large-scale online study is a unique probe into what drives preferences for internet memes, it is not immune to some limitations. First, the initial design choice to put the demographics questionnaire after the main survey prevented us from collecting information for many of our participants. Though this was corrected later, the dataset is missing a significant amount of demographic information. Fortunately, there was still a subset of respondents with demographic information for which we ran further analyses (see Appendix A). Still, of the known demographic sample, a significant majority are female and non-binary participants. Because of the explorative nature of this study, we did not conduct path analyses that could reveal the intricate structure of direct and indirect influences of emotions on the overall appreciation of internet memes. Additionally, we did not measure other common variables in empirical aesthetics like interest, awe, arousal, or curiosity. However, the richness of our dataset provides a glimpse into the potential applications of internet memes as user-generated naturalistic stimuli in the affective sciences. Finally, because of our stimuli, the generalizability of the study is confined to English-language internet memes without specific cultural references or dialects.

*2.4.9 Future Directions*

Future avenues of research for the aesthetics of internet memes are vast. Although we used split-sample strategies and cross-validation to avoid false discoveries, our exploratory results can be corroborated in later confirmatory experiments. Using a representative sample of the internet, future studies can also diligently explore the influence of age, gender, and other demographic variables on aesthetic preferences for internet memes. In addition to self-reporting, the use of psychophysiological measures like eye-tracking, facial expression analysis, or electrodermal activity can provide greater insights into cognitive and emotional mechanisms. Similar to art, internet memes have been shown to improve mental health in clinically depressed patients (Akram et al., 2020; Mastandrea et al., 2019). Future research could compare the effects of internet memes and traditional forms of art on mental health and well-being. Finally, although there is research from all over the world about internet memes (Gambarato & Komesu, 2018; Hakoköngäs et al., 2020; Mina, 2014; Moreno-Almeida & Gerbaudo, 2021; Ngwira, 2022), future studies could deliberately examine cultural differences in meme appreciation. This could include how varying cultural contexts, like cultural dimensions (Hofstede, 1984) influence preferences for memes, particularly around humor, processing fluency, and exclusivity.

In conclusion, this study sheds light on how cognitive processes, emotional responses, and social factors influence the appreciation of internet memes. Our findings demonstrate that memes, like other art forms, engage viewers through a balance of cognitive fluency and disfluency, and emotional resonance. However, amusement and humor still play the biggest role in the shaping of preferences. The preference for non-family memes highlights the value of creativity and novelty, while the role of positive emotions aligns with broader trends in art appreciation and emotional engagement. The findings of this study positions memes as not only ephemeral digital artifacts but as influential forms of creative expression that reflect and shape both individual and collective experiences.

# Chapter 3:

# Psychophysiological Differences in Fluent and Disfluent Stimuli

## 3.1 Introduction

Internet memes use social boundary-marking humor (Kuipers, 2009) to distinguish the insiders from the outsiders of a joke. Indeed, Study 1 found that perceived humor is the best predictor of internet meme appreciation. Humor is a two-step process of incongruity detection and resolution (Suls, 1972) and memes often leverage incongruity between image and text to evoke playful cognitive shifts through incongruity resolution (Yus, 2021). Insiders who resolve this incongruity feel a sense of shared humor, while outsiders might feel left out, affecting their overall appreciation. In addition to humor, Study 1 also showed that a balance of fluency and disfluency was a key factor behind the appreciation of internet memes (Ayele et al., 2025). Fluent processing of a stimulus is characterized by being easier to understand, fast, and evoking immediate positive affect (Reber et al., 2004). Disfluent processing, instead, is difficult to understand, slow, and leads to immediate negative affect. These affective reactions are often unconscious and attributed to the stimulus, either increasing or decreasing its evaluation.

However, some individuals may choose to further the cognitive elaboration of a fluent or disfluent stimulus. These individuals have a cognitive motivation, perhaps stemming from a need for cognition (NFC), a need to structure or integrate information in meaningful ways (Cacioppo & Petty, 1982; Cohelo et al., 2018) or a need for cognitive closure (NFCC), a motive to reduce or avoid ambiguity (Webster & Kruglanski, 1994; Roets & Van Hiel, 2007). With sufficient cognitive elaboration, the negative affect of disfluency can be resolved and transformed into a positive feeling (Graf & Landwehr, 2015). If this increase in fluency happens suddenly, an Aha experience occurs (Topolinski & Reber, 2010), the reaction that typically occurs at a moment of sudden insight into a problem or other puzzling issue. Aha experiences are typically characterized as a sudden increase in understanding accompanied by positive affect and an increase in a perception of truthfulness of a solution (Skaar & Reber, 2020; Topolinski & Reber, 2010). However, disfluency can persist even after cognitive processing, leaving only a negative state of confusion.

To better understand these affective shifts, researchers have turned to physiological measures such as facial electromyography (EMG), which provides a window into implicit emotional responses. Unlike the self-report measures reported in Study 1, facial EMG measures emotion on the facial expression component of emotions instead of the subjective feeling component (Scherer, 2005). Increased activity in the zygomatic area has been shown to correlate with felt subjective positive emotions, while increased activity in the corrugator area has been shown to correlate with felt negative emotions (Künecke et al., 2014; Larsen et al., 2003; Neta et al., 2009; Tan et al., 2011, 2012). Facial EMG has been used to show affective changes due to cognitive processing. For example, a study using perceptual problems like bi-stable illusions (Lindell et al., 2022) found that zygomatic activity increased while corrugator activity decreased the moment a solution to the illusion was found. Importantly, facial EMG has been used to capture affective differences due to processing fluency (Gerger et al., 2011; Topolinski et al., 2009; Winkielman et al., 2015; Witvliet & Vrana, 2007) with greater levels of fluency associated with larger amplitudes of the zygomatic muscular activity and lower amplitudes of the corrugator muscle activations. In addition to sensitivity for facial muscular activity, EMG has an excellent temporal resolution that can detect exactly when spontaneous facial expressions occur. In a previous study on autism and emotional mimicry, researchers were able to detect differences in temporal delays in spontaneous facial EMG activity in autism and healthy control subjects, even without detecting a difference in amplitude (Oberman et al., 2009).

While facial EMG provides valuable insights into the muscular activity associated with emotional expressions, researchers often complement it with measures of autonomic nervous system activity to gain a more comprehensive understanding of emotional and physiological responses. One such measure is electrodermal activity (EDA), which captures changes in skin conductance and serves as an indicator of sympathetic nervous system arousal (Delplanque et al., 2009; Dimberg, 1982; Thompson et al., 2016). Variations in skin conductance response (SCR) are stimulus related changes in the sympathetic nervous system (Benedek & Kaernbach, 2010). SCR has been used to track variations in physiological arousal during the viewing of visual stimuli and its influence on aesthetic judgment (Gerger et al., 2018). Several studies on humor have also shown that moderate arousal is linked to the perception and appreciation of humor (Berlyne et al., 1963; Noseworthy et al., 2014; Ruiz-Padial et al., 2023).

### *3.1.1 Study Objectives*

From Study 1, we observed that fluency and disfluency play a significant positive role in appreciation of internet memes. In this study, we further investigate how processing fluency plays a role in the affective processing of internet memes with psychophysiological tools. We capture the moment-to-moment dynamics of facial expressions with facial EMG) and arousal with SCR. We use the dataset of validated internet memes from Study 1 to select internet memes that evoked the highest fluency and disfluency scores, respectively. Prior to data collection for the first experiment, we pre-registered five hypotheses (https://doi.org/10.17605/OSF.IO/P9N54):

1. We expected participants to perceive fluent internet memes as easier to process than disfluent ones [Manipulation check].

2. In line with previous research on processing fluency and aesthetic evaluations, we predicted that there would be a significant difference in the aesthetic liking of fluent and disfluent internet memes.

3. In addition, we expected that fluent internet memes would relate to greater activation of the zygomatic or smiling muscles.

4. We expected disfluent memes would relate to greater activation of the corrugator or frowning muscles.

5. Finally, due to the nature of complex information contained in disfluent internet memes, we hypothesized that disfluent internet memes would cause greater arousal, as evidenced by the magnitude of skin conductance response.

### 3.2 Experiment 1 Methods

#### *3.2.1 Participants*

An a priori G*power 3.1.3 (Faul et al., 2007) analysis indicated N = 34 to detect a medium effect size of d = 0.5 with a power of 1–β = .80, $\alpha$ = .05, and a critical $t$ = 2.034 for a matched pairs t-test. We recruited 34 participants (18 women) at the University of Pisa for a 30-euro reward. At the request of the ethical committee, participants anonymously report their age by selecting an age range. Most participants were between the age range of 24-26 with the minimum age range of 21-23 and the maximum age range of 39-41. Participants were briefed about experimental procedures and signed consent forms prior to the start of the experiment. EDA recordings for two participants could not be used due to technical issues. Therefore, EMG analyses were performed on N = 34 participants, and EDA analyses were performed on N = 32 participants.

#### *3.2.2 Stimuli*

Fluent and disfluent internet memes were selected from a larger database of validated multimodal internet memes (Ayele et al., 2025). We selected 42 memes at the 75th percentile of fluency scores and 42 memes at the 75th percentile of disfluency scores, for a total of 82 internet memes. Participants were presented with a randomized subset of 10 fluent and 10 disfluent memes.

*3.2.3 Measures*

3.2.3.1 Behavioral

In each trial, participants were asked:

A. "How much did you like this?" on a numerical scale of 1-10, 1 meaning "dislike very much" and 10 meaning "like very much",

B. "How easy was it to process this?" from 1-10, 1 meaning "very difficult" to process and 10 meaning "very easy to process".

Dwell time was calculated as the duration in seconds the participants looked at the stimulus before clicking the 'continue' button. We corrected outliers for dwell times that exceeded three standard deviations from the mean. At the end of the experiment, participants also completed three questionnaires. First, they reported their previous familiarity with internet memes, how active they were on social media, and their attitude towards internet memes on a 7-point Likert scale. Next, they took the 6-point Need for Cognition questionnaire (Cohelo et al., 2018). Finally, they completed the Need for Cognitive Closure scale (Webster & Kruglanski, 1994; Roets & Van Hiel, 2007). The Need for Cognitive Closure scale gives a score between 15 and 90. People with a score up to 30 are classified as low NFCC and scores between 75-90 are classified as high NFCC (Webster & Kruglanski, 1994; Roets & Van Hiel, 2007).

3.2.3.2 Facial Electromyography (EMG)

Facial EMG activity was recorded using the Delsys Trigno Wireless Biofeedback System and a Trigno Duo sensor. One electrode of the Duo sensor was placed on the *M. zygomaticus major* and the other on the *M. corrugator supercilii* regions, complying with the guidelines of Fridlund & Cacioppo (1986). The ground electrode was mounted in a location distant from the corrugator on the forehead. The raw EMG signals were sampled at a frequency of 2048 Hz. Data was preprocessed using Python 3.9 and the Scipy Signal library. The DC offset was removed from the signal by subtracting the mean. Then, a 20 hz-450hz bandpass filter was applied. The signal was rectified and smoothed using a 10 Hz lowpass filter. Statistical analyses were performed on within-participant *z*-transformed and log-normalized data of each trial. First, the mean of individual trials was compared to the overall mean of the entire recording. Trial means above or below three standard deviations of the recording mean were excluded from further analysis. This resulted in no trial removals for zygomatic activity and 3% of trials for corrugator activity. Then, mean EMG activity was computed by dividing the trial average EMG activity by the baseline average EMG activity 5000ms before stimulus onset. We used the NeuroKit2 *find_peaks* algorithm (Makowski et al., 2021) to further explore peak behaviors in zygomatic and corrugator activity. Based on previous research, the minimum relative height threshold was set at 1.96 standard deviations (Li et al., 2018). We calculated the normalized frequency of peaks by dividing the number of peaks in a trial by the time window and extracted the latency of the maximum peak in the window.

3.2.3.3 Electrodermal Activity (EDA)

EDA activity was recorded using the BioPac MP150 GSR recording unit. Two Ag/AgCl electrodes were placed on the index and middle finger of the non-dominant hand. The raw signal was sampled at 500 Hz. The signal was down sampled to 50hz, transformed into a z-score, decomposed into phasic, tonic, and noise components using the cvxEDA algorithm (Greco et al., 2015), z-transformed, log-normalized, and epoched into trials of stimuli presentation. Then, SCR magnitude was calculated as the maximum amplitude of the skin conductance response in the trial. We also used the NeuroKit2 *find_peaks* algorithm (Makowski et al., 2021) with a minimum relative height threshold of 0.1 (Lykken et al., 1968) to explore peak behavior in the skin conductance response. Like the EMG data, we calculated the normalized frequency of peaks and maximum peak latency for each trial.

*3.2.4 Procedure*

All procedures followed the principles stated in the Declaration of Helsinki and were approved by the Comitato Etico Congiunto per la Ricerca della Scuola Sant'Anna e della Scuola Normale, protocol number 39/2022. Before electrode placement, an alcohol wipe was used to clean the fingers on the non-dominant hand, the left eyebrow, the left cheek, and the forehead. Then, electrodes were attached to monitor EMG and EDA activity. Participants were presented with 20 internet memes in a random order. Each trial was preceded by a 5-second fixation cross. Participants were allowed to dwell on the memes and used a "continue" button to advance to the ratings. They evaluated their aesthetic liking and ease of processing for each meme. A 35-second ITI separated the memes to allow EMG and EDA signals to return to baseline before the subsequent stimuli.

## 3.3 Results

*3.3.1 Behavioral*

A two-tailed paired t-test was used to compare ease of processing, aesthetic liking, and dwell times in fluent and disfluent internet memes (Figure 3.1). We found that the ease of processing for fluent memes was perceived as significantly easier than disfluent memes (Fluent M= 8.72, SD = 0.96; Disfluent M = 6.00, SD = 1.31; $t(33) = 10.98$, $p < 0.001$). This finding confirms that our independent variable (fluency-inducing and disfluency-inducing stimuli) was effectively manipulated. We also found that fluent memes were liked significantly more than disfluent memes (Fluent M = 6.61, SD = 1.54; Disfluent M = 5.00, SD = 1.37; $t(33)= 6.32$, $p < 0.001$). Moreover, dwell times for fluent internet memes were significantly shorter than disfluent memes (Fluent M = 10.46 sec, SD = 5.30; Disfluent M = 15.60 sec, SD = 8.07; $t(33) = -6.26$, $p < 0.001$).

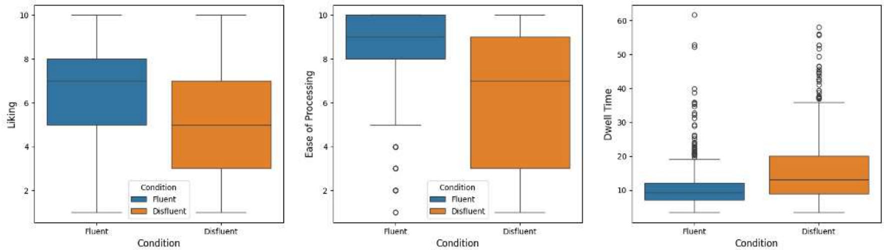


***Figure 3.1:*** *Box plot of behavioral differences in fluent and disfluent internet memes.*

*3.3.2 Individual Differences*

On a 7-point Likert scale, participants were on average moderately familiar with internet memes (M = 5.67, SD = 1.39), were moderately active on social media (M = 4.71, SD = 1.44), and moderately liked internet memes (M = 5.88, SD = 1.44). On a five-point scale, participants on average had a moderate need for cognition (M = 3.52, SD = 0.62). To determine Need for Cognitive Closure, a score of 1-90 was calculated as suggested (Webster & Kruglanski, 1994; Roets & Van Hiel, 2007). Many participants did not fall into the ranges of low or high NFCC with an average score of 57.5 (SD = 11.86). We ran three linear mixed effects models using liking, understanding, and dwell time as dependent variables, participant and meme ID as random variables, personality characteristics as predictor variables (Table 3.1). We found that no personality characteristics had a significant effect on the liking of internet memes. However, previous familiarity and attitude towards memes increased ratings of understanding. Similarly, we found that previous familiarity with memes decreased dwell time overall. We did not find any significant main effects of need for cognition nor need for cognitive closure on any behavioral measures.

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**Liking**

| *Predictors* | *Estimates* | *CI* | *p* |
|---|---|---|---|
| (Intercept) | 7.20 | 2.48 – 11.91 | **0.003** |
| **Type [Disfluent]** | **-1.45** | **-2.10 – -0.80** | **<0.001** |
| NFCC | -0.00 | -0.06 – 0.05 | 0.849 |
| NFC | -0.07 | -1.01 – 0.86 | 0.876 |
| Familiarity | -0.20 | -0.65 – 0.24 | 0.363 |
| Social Media Activity | -0.08 | -0.50 – 0.33 | 0.687 |
| Attitude | 0.24 | -0.43 – 0.92 | 0.479 |

**Understanding**

| *Predictors* | *Estimates* | *CI* | *p* |
|---|---|---|---|
| (Intercept) | 7.04 | 4.81 – 9.26 | **<0.001** |
| **Type [Disfluent]** | **-2.81** | **-3.55 – -2.06** | **<0.001** |
| NFCC | -0.02 | -0.04 – 0.01 | 0.125 |
| NFC | -0.07 | -0.51 – 0.36 | 0.746 |
| **Familiarity** | **0.29** | **0.08 – 0.50** | **0.006** |
| Social Media Activity | -0.16 | -0.35 – 0.04 | 0.115 |
| **Attitude** | **0.38** | **0.06 – 0.70** | **0.019** |

| Dwell Time | | | |
|---|---|---|---|
| *Predictors* | *Estimates* | *CI* | *p* |
| (Intercept) | 22.04 | 1.02 – 43.06 | **0.040** |
| **Type [Disfluent]** | **7.10** | **3.29 – 10.91** | **<0.001** |
| NFCC | 0.03 | -0.20 – 0.26 | 0.770 |
| NFC | -0.17 | -4.35 – 4.02 | 0.938 |
| **Familiarity** | **-4.06** | **-6.04 – -2.07** | **<0.001** |
| Social Media Activity | 0.33 | -1.53 – 2.19 | 0.728 |
| Attitude | 1.56 | -1.49 – 4.62 | 0.316 |

***Table 3.1:*** *Linear Mixed effects results of personality characters on Liking, Understanding, and Dwell Time*

### *3.3.3 Facial EMG*

We found no significant differences in the mean zygomatic activity for fluent and disfluent memes (Fluent M = 0.018 mV, SD = 0.62; Disfluent M = 0.025 mV, SD = 0.51; $t(33) = 0.62$, $p = 0.54$) . There were also no significant differences in the mean corrugator activity in fluent and disfluent memes (Fluent M = 0.03 mV, SD = 0.52; Disfluent M = -0.02 mV, SD = 0.35; $t(32) = 0.61$, $p = 0.56$). Regarding muscular reactivity, we found a significant difference in the frequency of peaks in the zygomatic activity (Fluent M = 0.21, SD = 0.08; Disfluent M = 0.18 peaks, SD = 0.07; t(33) = 4.06, p < 0.001) and in the corrugator activity (Fluent M = 0.24 peaks, SD = 0.07; Disfluent M = 0.22, SD = 0.06; t(32) = 3.49, p < 0.01). Fluent internet memes had more peaks in each time window, suggesting higher reactivity to fluent stimuli compared to disfluent ones. In terms of temporal differences, there was a significant difference in the latency of the maximum peak in the zygomatic (Fluent M = 5.73 sec, SD = 4.09; Disfluent M = 9.38 sec, SD = 5.79; $t(33) = -6.28$, $p < 0.001$) and corrugator (Fluent M = 5.65 sec, SD = 5.01; Disfluent M = 9.54 sec, SD = 9.44; $t(32) = -3.68$, $p < 0.001$) activity. Fluent stimuli elicited faster muscular responses for both zygomatic and corrugator activity.

*3.3.4 EDA*

A two-tailed paired t-test was used to detect differences in phasic skin conductance response (SCR) between fluent and disfluent internet memes. We found there was a significant difference in the magnitude of SCR (Fluent M = -0.08 μS, SD = 0.97; Disfluent M = 0.06 μS, SD = 0.93; $t(31) = -3.82$, $p < 0.001$). As predicted in our pre-registered hypothesis, the magnitude of SCR for disfluent memes was higher than for fluent memes, even if there were no observable differences in the average activity. In addition, we found a significant negative correlation between skin conductance magnitude and liking ($r = -0.22$, $p < 0.01$) and skin conductance magnitude and ease ($r = -0.17$, $p < 0.05$). This suggests that higher levels of arousal were related to a decrease in ease of processing and liking.

We also found a significant difference in the frequency of SCR peaks in fluent and disfluent memes (Fluent M = 0.08 peaks, SD = 0.02; Disfluent M = 0.07 peaks, SD = 0.02; $t(31) = 4.58$, $p < 0.001$) and a significant difference in the latency of the maximum peak (Fluent M = 1.33 sec, SD = 2.32; Disfluent M = 4.53 sec, SD = 5.07; $t(31) = -4.51$, $p = 0.001$). Like the EMG results, fluent internet memes had more SCR reactivity in a trial and were faster to reach their maximum peaks compared to disfluent memes.

### *3.3.5 Correlations between Physiology, Behavior, and individual Differences*

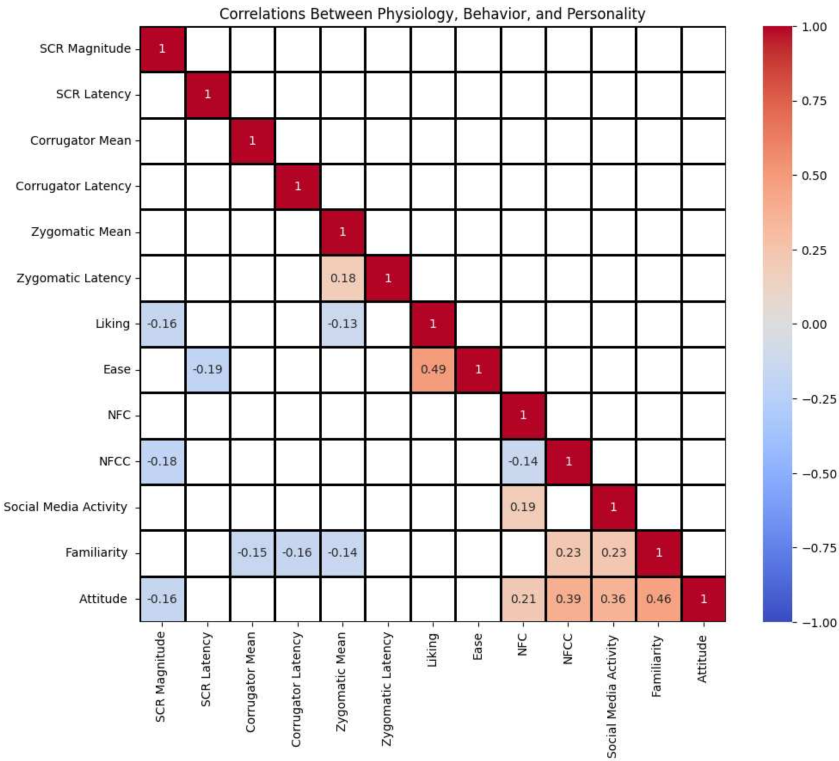


***Figure 3.2:*** *Correlation matrix of physiology, behavioral, and individual differences measures showing only significant correlations(p >0.003) after Bonferroni correction.*

When looking at the Pearson correlations between measured variables (Figure 3.2), we found several significant relationships. Familiarity with internet memes was negatively correlated with the mean and latency of corrugator activity as well as zygomatic mean activity. This suggests that greater familiarity with memes is related to more efficient emotional processing, as evidenced by earlier corrugator activation and lower overall EMG activity. Familiarity might allow individuals to quickly recognize and understand memes, reducing the intensity of their emotional responses. Additionally, we found that the mean activity of the zygomatic muscle was positively correlated with its latency. This suggests that stronger zygomatic activity (smiling) is associated with slower activation, which could indicate that more intense smiling responses are less automatic and potentially more deliberate or controlled. We also found that the mean of zygomatic activity was negatively correlated with liking. This is a surprising result, as zygomatic muscle activity typically indicates positive emotions; however, our correlational result suggest higher zygomatic activity is related to lower liking of memes.

We also found that liking was negatively correlated with the magnitude of skin conductance. This suggests that memes eliciting higher physiological arousal are less liked, possibly because they are overwhelming, confusing, or evoke negative emotions such as anxiety or discomfort. Additionally, skin conductance magnitude was negatively correlated with need for cognitive closure and attitude towards internet memes. This indicates that individuals who prefer clear answers (high need for cognitive closure) find highly arousing memes less appealing, possibly because such memes are perceived as chaotic or intellectually unsatisfying. Finally, we found that SCR latency was negatively correlated with ease of processing. This suggests that memes that are easier to process elicit quicker physiological arousal, possibly because they are more immediately engaging or impactful.

When considering correlations between behavior and individual differences, we found that attitude toward internet memes was positively correlated with need for cognition, need for cognitive closure, social media activity, and familiarity. This suggests that people who enjoy memes tend to be more cognitively engaged, prefer clear answers, are more active on social media, and are more familiar with meme culture. Memes may appeal to individuals who enjoy both intellectual stimulation and social networking platforms. Additionally, familiarity with memes was positively correlated with both need for cognitive closure and social media activity, indicating that individuals who frequently encounter memes may also have a stronger preference for clear and structured information. Notably, we found a negative correlation between need for cognition and need for cognitive closure. This suggests that individuals who enjoy deep thinking (high need for cognition) are less likely to seek definitive answers (low need for cognitive closure), and vice versa. These traits may represent distinct cognitive styles that influence how people engage with memes, as both need for cognition and need for cognitive closure were positively correlated with attitude toward memes. Finally, as expected, we observed a positive correlation between liking and ease of processing, reinforcing the idea that fluently processed memes tend to be more enjoyable.

### 3.4 Discussion

In this first experiment, we observed several differences between fluent and disfluent internet memes. Behavioral ratings confirmed that our fluency manipulation was effective, with fluent memes being processed more easily, more quickly, and receiving higher liking ratings. These findings provide further evidence of the processing fluency effect in meme appreciation. Additionally, previous familiarity with memes was associated with decreased dwell time, supporting the role of fluency in recognition and understanding. However, familiarity did not increase liking, suggesting that mere exposure does not necessarily enhance aesthetic or affective evaluations. Other personality traits, including need for cognition and need for cognitive closure, did not significantly influence ratings of liking or understanding, nor did they affect the time participants spent looking at the memes.

Despite these behavioral differences, we did not observe significant differences in average EMG activity for the zygomatic or corrugator muscle areas. However, exploratory analyses into peak behaviors revealed differences in the peak frequencies and peak latencies of all physiological signals. Fluent internet memes exhibited increased peak frequencies and reached their maximum physiological responses faster than disfluent memes. This pattern suggests that fluently processed stimuli may evoke more immediate, efficient physiological responses.

One of the most surprising findings was the negative correlation between zygomatic activity and liking. While zygomatic activity is typically associated with positive affect (Dimberg, 1982), the mean of zygomatic activation was negatively correlated with liking in our study. This suggests that more pronounced zygomatic responses do not necessarily indicate genuine enjoyment of memes. Instead, stronger activation may reflect a more effortful or socially modulated response rather than a direct index of amusement. Additionally, familiarity with memes was negatively correlated with both corrugator and zygomatic activity, suggesting that individuals who are more familiar with memes exhibit more efficient emotional processing, possibly recognizing and categorizing the content more quickly, leading to attenuated facial EMG responses.

Furthermore, we found that disfluent memes elicited greater skin conductance responses than fluent memes, in line with our pre-registered hypothesis. This suggests that disfluent memes may induce heightened arousal, potentially due to their increased cognitive demands or ambiguity. Moreover, skin conductance magnitude was negatively correlated with need for cognitive closure, implying that individuals who prefer structured, unambiguous information may find highly arousing memes less appealing, possibly perceiving them as chaotic or intellectually unsatisfying. Additionally, SCR latency was negatively correlated with ease of processing, reinforcing the idea that fluently processed memes trigger quicker physiological responses, likely due to their more immediate engagement.

At a broader level, individual differences played a significant role in shaping meme engagement. Attitude toward memes was positively correlated with need for cognition, need for cognitive closure, social media activity, and familiarity, suggesting that people who enjoy memes tend to be more cognitively engaged, prefer clear answers, and are more immersed in online culture. Familiarity with memes was also positively correlated with need for cognitive closure and social media activity, reinforcing the idea that exposure to memes is linked to both cognitive and social variables. Additionally, we observed a negative correlation between need for cognition and need for cognitive closure similar to prior research on the relationship of the two measures (Petty & Jarvis, 1996, Webster & Kruglanksi, 1994). These results suggest that individuals who enjoy deep thinking are less likely to seek definitive answers, and vice versa. These distinct cognitive styles may influence how individuals interpret and engage with memes, as both traits were positively associated with attitudes toward memes. Finally, as expected, we found a strong positive correlation between liking and ease of processing, reinforcing the well-established link between fluency and affective appraisal.

Despite these novel findings, some limitations must be acknowledged. Although our physiological peak analyses revealed meaningful differences in response patterns between fluent and disfluent memes, we did not instruct participants to explicitly indicate when they understood the meme. As a result, we cannot conclude that the maximum physiological response corresponds to the precise moment of comprehension. Additionally, our study focused exclusively on internet memes, which are inherently humorous and multimodal stimuli. This raises the possibility that differences in processing fluency may be confounded with the complex nature of these stimuli. To address this, we conducted a follow-up experiment including black-and-white Mooney images in addition to memes and explicitly instructed participants to indicate an 'aha' moment to further investigate the effects of fluency on perceptual and cognitive processing.

### 3.5 Experiment 2 Introduction

In our second experiment, we reuse memes from Experiment 1 and introduce Mooney images (Figure 3.3) as non-humorous control stimuli. Mooney images are high-contrast, black-and-white visual stimuli that are used in cognitive and psychological research. Mooney images contain minimal explicit information and are challenging to interpret. But, once solved, they elicit positive affective responses similar to an aha moment (Van de Cruys et. al, 2021). We use Mooney images to serve as a non-humorous comparison to internet memes since they are perceptual puzzles that could possibly evoke similar affective responses. To manipulate the fluency of the Mooney images, we use a validated dataset of Mooney stimuli from a previous study (Van De Cruys et. al, 2021). In this study, researchers propose 'semantic entropy' (SE) as a proxy measure of uncertainty or prototypicality of Mooney images. A high semantic entropy of Mooney images suggests poly-interpretability or more diverse guesses of solutions. Instead, lower semantic entropy suggests more common or prototypical guesses from participants. We propose that semantic entropy could be a viable metric for the fluency of a Mooney image. We used Mooneys with lower semantic entropies as fluent Mooneys and those with higher semantic entropies as disfluent stimuli.

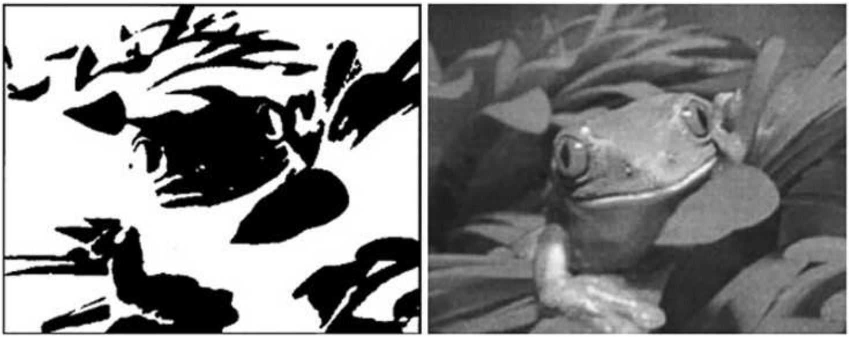

***Figure 3.3:*** *An example of a Mooney image along with its solution. Adapted from Van de Cryus et. al, 2021.*

## 3.6 Methods

### *3.6.1 Participants*

For the second experiment, we conducted another a priori G*power 3.1.3 (Faul et. al, 2007) analysis. The test resulted in a minimum sample of indicated N = 24 to detect an effect size of d = 0.6, the smallest significant effect size from Experiment 1, with a power of $1–\beta = .80$, $\alpha = .05$, and a critical t = 2.06 for a paired t-test. We recruited 24 new participants (14 female) at the University of Pisa in exchange for a 30-euro reward, under the same ethical protocol of Experiment 1. Participants were briefed about experimental procedures and signed consent forms prior to the start of the experiment. EDA recordings and corrugator recordings for two participants could not be used due to technical recording issues. Upon visual examinations of each block, one recording from the meme condition and three recordings from the Mooney conditions were not used due to recording failure. Therefore, EMG analyses were performed on N = 22 participants, EDA analyses for memes were performed on N = 21 participants, and EDA analyses for Mooney conditions were performed on N = 19 participants.

*3.6.2 Stimuli*

Like Experiment 1, participants were presented 20 randomly selected fluent and disfluent internet memes from the validated dataset of Study 1. In the second experiment, participants were also presented with Mooney stimuli collected and validated in a different study (Van De Cruys et. al, 2021). The Mooney stimuli were categorized as low SE or high SE based on the 75th percentile scores of semantic entropies. Each Mooney stimulus belonged to one of four categories: food, animal, person, or object. Participants were presented with 20 randomly selected low SE and high SE Mooney stimuli.

*3.6.3 Procedure*

We followed the same recording procedure and electrode placement as Experiment 1 for the second experiment. Participants were presented with counterbalanced blocks of meme and Mooney stimuli. The stimuli within the blocks were presented in a random order. For the meme block, participants were asked to press 'space' when they understood the meme or 'continue' if they did not understand. For the Mooney block, participants were asked to identify the category of the image as food, animal, person, or object or press 'continue' if they did not know. From here forward, we will refer to this as the "moment of resolution" regardless of whether participants reported understanding or choose to continue without understanding. Each trial was preceded by a 5000 ms fixation cross and a 5000 ms delay after stimulus presentation. Then, participants gave behavioral ratings for the stimuli. Each trial was separated by a 30-second ITI.

*3.6.4 Measures*

3.6.4.1 Behavioral

After the presentation of each stimulus, participants were asked to indicate whether they experienced an ‘Aha’ moment using ‘y’ for yes and ‘n’ for no. ‘Aha’ moments were defined to the participants as a moment of sudden insight after some difficulty in solving a problem or processing information (Topolinski & Reber, 2010). Then, participants rated:

C. “How much did you like this?” on a numerical scale of 1-10, 1 meaning “dislike very much” and 10 meaning “like very much”,

D. “How easy was it to process this?” from 1-10, 1 meaning “very difficult” to process and 10 meaning “very easy to process”.

E. “How well did you understand this” from 1-10, 1 meaning “I did not understand it at all” and 10 meaning “I understood it completely”

We also use “dwell time” as a behavioral measure of how long, in seconds, it took participants to arrive at the moment of resolution from the stimulus onset.

3.6.4.2 Physiology

EMG and EDA data were recorded, preprocessed, and analyzed in the same manner and with the same equipment as Experiment 1. To further investigate physiological behavior at the moment of resolution, preprocessed data was separately epoched into 5000ms before the indicated moment of resolution and 5000ms after. Six linear mixed-effects model (LMM) were fitted for zygomatic, corrugator, and SCR for meme and Mooney conditions using the lmer package in R. Rather than assuming a continuous linear relationship between time and physiological activity, time was treated as a categorical factor to capture potential nonlinear changes in facial muscle activity before, during, and after resolution This approach allows for a more precise estimation of activity at each discrete time point, enabling the identification of the first significant deviation from baseline and the peak response at closure. The model included Time (categorical), and Condition (fluent vs disfluent) as fixed effects, with Stimulus and Participant as random effects. We used Type III ANOVA with Satterthwaite's method to test our model.

### 3.7 Results

#### *3.7.1 Fluent vs Disfluent Trials*

##### 3.7.1.1 Behavioral

When comparing internet meme stimuli to Mooney stimuli, we found several significant differences in the ratings and behavior of participants. We found that memes were liked more (Meme M = 6.05, SD = 1.15, Mooney M = 4.75, SD = 1.44, t(23) = 3.78, p = <0.001), understood more (Meme M = 7.50, SD = 0.88, Mooney M = 4.00, SD = 1.20, t(23) = 11.06, p = <0.001), easier to process (Meme M = 7.36, SD = 0.92, Mooney M = 3.93, SD = 1.31, t(23) = 10.43, p = <0.001), and had faster dwell times (Meme M = 12.85 sec, SD = 5.78 sec, Mooney M = 33.78 sec, SD = 20.73 sec, t(23) = -5.19, p = <0.001). These findings indicate that memes were overwhelmingly processed more fluently than Mooney images. Furthermore, we found evidence of the processing fluency effect within the internet meme condition. Compared to disfluent memes, fluent memes were liked more (Fluent M = 6.70, SD = 1.33, Disfluent M = 5.41, SD = 1.47, t(23) = 3.91, p = <0.001), understood more (Fluent M = 8.78, SD = 1.02, Disfluent M = 6.22, SD = 1.30, t(23) = 8.23, p = <0.001), were easier to process (Fluent M = 8.73, SD = 0.97, Disfluent M = 5.99, SD = 1.35, t(23)= 9.13, p = <0.001), and had faster dwell times (Fluent M = 9.12 s, SD = 4.07, Disfluent M = 16.59 s, SD = 8.19, t(23)= -6.27, p = <0.001). When comparing low SE and high SE Mooney images, we found no significant differences in liking (Low SE M= 4.72, SD = 1.54, Disfluent M = 4.77, SD = 1.54, t(23)= -0.30, p = 0.76), understanding (Low SE M = 3.90, SD = 1.25, High SE M = 4.02, SD = 1.40, t(23)= -0.58, p = 0.57), ease of processing (Low SE M = 3.88, SD = 1.33, High SE M = 3.93, SD = 1.47, t(23)= -0.30, p = 0.76), nor dwell times (Low SE M = 34.82 sec, SD = 20.63 sec, High SE M = 32.96 sec, SD = 20.14 sec, t(23)= 1.20, p = 0.20).

These results show that there is no evidence that semantic entropy directly maps onto fluency.

3.7.1.2 Facial EMG

When comparing mean EMG activity for fluent and disfluent memes, we found no significant differences for zygomatic activity ($t(22) = 1.22$, $p = 0.23$) nor corrugator activity ($t(21) = 1.54$, $p = 0.13$) (Table 6). For Mooney images (Table 7), we found no significant differences in zygomatic activity ($t(22) = 1.50$, $p = 0.15$) but found that corrugator activity was greater for low SE Mooney images ($t(22) = 2.87$, $p < 0.01$). Similar to the results of Experiment 1, we did not find large consistent differences in mean EMG activity due to processing fluency effects. Although, we did find weak but significant positive correlations between zygomatic and corrugator activity in memes ($r = 0.10$, $p = 0.03$) and Mooney ($r = 0.14$, $p = 0.003$) blocks.

When looking at temporal differences, we find that processing fluency exhibits similar effects as Experiment 1. Notably, we found that maximum peak latency is longer in disfluent memes for both zygomatic ($t(21) = -3.94$, $p < 0.001$) and corrugator ($t(21) = -4.20$, $p < 0.001$) activity. Moreover, we found that the frequency of zygomatic peaks was significantly higher for fluent memes compared to disfluent memes ($t(21) = 2.39$, $p = 0.02$). This was not the case for Mooney images, where we found no significant peak latency differences in zygomatic ($t(21) = -0.82$, $p = 0.41$) nor corrugator ($t(21) = -0.26$, $p = 0.79$) activity for low and high SE images. No other significant differences were found for the frequency of fEMG peaks.

3.7.1.3 EDA

We found results approaching significance when comparing differences in SCR magnitude for fluent and disfluent memes ($t(20) = -2.00$, $p = 0.06$) (Table 3.2). There were no significant differences in SCR magnitude between low SE and high SE Mooney images ($t(18) = 0.48$, $p = 0.64$) (Table 3.3). For temporal differences, we found that there was a significant difference in maximum peak latency between memes and Mooney images ($t(18) = -2.70$, $p = 0.01$) and a difference approaching significance regarding fluent and disfluent internet memes ($t(20) = -2.04$, $p = 0.05$). Furthermore, we found that internet memes had a higher frequency of SCR peaks compared to Mooney stimuli ($t(18) = 3.22$, $p < 0.01$), but no other differences in the frequency of SCR peaks were found.

| Internet Memes | | | |
|---|---|---|---|
| Measure | Condition | Mean | SD |
| Zygomatic | Fluent | 0.04 | 0.81 |
| | Disfluent | -0.04 | 0.80 |
| Corrugator | Fluent | 0.05 | 0.87 |
| | Disfluent | -0.01 | 0.88 |
| SCR | Fluent | 2.04 | 0.92 |
| | Disfluent | 2.56 | 1.91 |

***Table 3.2:*** *Means and SD of Physiological Measurements for Internet Memes*

| Mooney Images | | | |
|---|---|---|---|
| Measure | Condition | Mean | SD |
| Zygomatic | Low SE | 0.01 | 0.86 |
| | High SE | -0.07 | 0.77 |
| Corrugator | Low SE | 0.05 | 0.71 |
| | High SE | -0.13 | 0.66 |
| SCR | Low SE | 2.15 | 1.56 |
| | High SE | 2.11 | 1.44 |

***Table 3.3:*** *Means and SD of Physiological Measurements for Mooney Images*

### *3.7.2 Correlations between physiology and behavior*

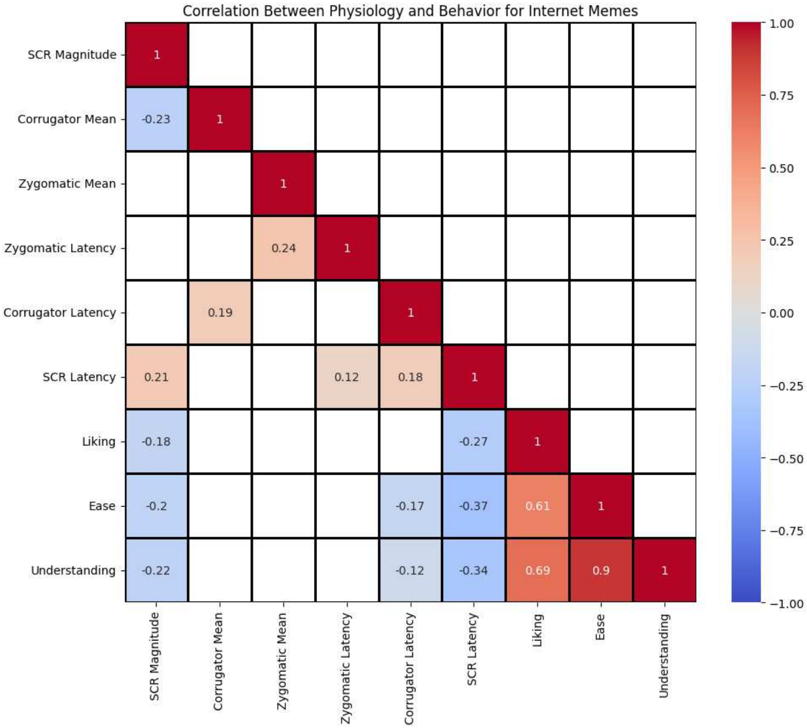


***Figure 3.4:*** *Correlation matrix between physiology and behavior for internet memes showing only significant correlations(p >0.005) after Bonferroni correction.*

Correlational analysis for internet memes (Figure 3.4) surprisingly revealed a negative correlation between skin conductance response (SCR) magnitude and corrugator activity, indicating that memes eliciting stronger physiological arousal were associated with less frowning. Additionally, SCR magnitude correlated positively with SCR latency, suggesting that higher arousal responses tended to occur with a delay. Memes that elicited stronger SCR responses were also rated lower in liking, ease, and understanding, suggesting that higher arousal was associated with more difficult or less enjoyable meme processing. Similarly, longer SCR latencies were linked to lower ratings of liking, ease, and understanding, further indicating that memes that took longer to trigger an autonomic response were perceived as harder to process and less appealing.

Corrugator activity was found to correlate positively with corrugator latency, while zygomatic activity also correlated positively with its latency, suggesting that both frowning and smiling responses followed a consistent temporal pattern. Notably, longer corrugator response times were associated with lower ease and understanding ratings, suggesting that memes requiring more time to trigger a frowning response were also perceived as harder to process. Again, a strong positive correlation was found between liking, ease, and understanding, confirming that memes that were easier to process were also more liked and better understood.

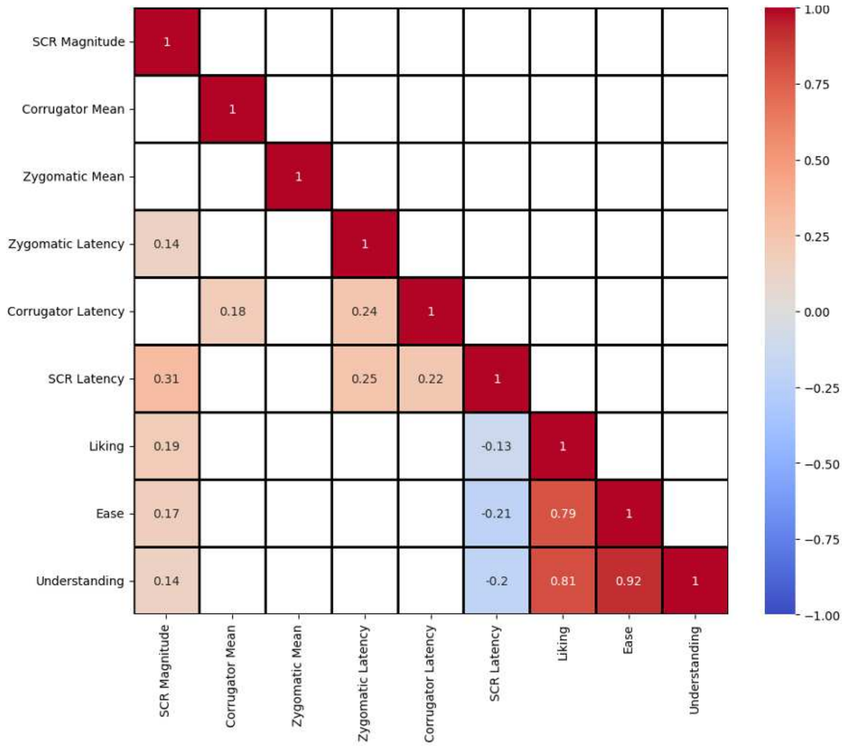


***Figure 3.5:*** *Correlation matrix between physiology and behavior for Mooney images showing only significant correlations(p >0.005) after Bonferroni correction.*

Facial muscle activity for Mooney images (Figure 3.5) also showed significant correlations, with corrugator mean activity positively correlating with its latency, indicating that greater frowning intensity was associated with a delayed response. Furthermore, zygomatic latency, corrugator latency, and SCR latency were all positively correlated, suggesting that the timing of facial muscle responses and autonomic arousal were interconnected during the processing of Mooney images. Analysis also revealed a positive correlation between skin conductance response (SCR) magnitude and zygomatic latency, indicating that stronger physiological arousal (as measured by SCR) was associated with a delayed smiling response. Additionally, SCR latency positively correlated with SCR magnitude, suggesting that higher arousal levels were accompanied by slower autonomic responses. A positive correlation was found between liking, ease, and understanding, reinforcing the idea that Mooney images that were more easily processed were rated higher in terms of enjoyment and comprehension, regardless of their semantic entropy. However, SCR latency was negatively correlated with liking, ease, and understanding, suggesting that slower physiological responses were associated with lower ratings of these subjective measures, further supporting the role of processing fluency in Mooney image evaluation.

*3.7.3 Aha vs No-aha Trials*

Participants reported resolving the meaning of the meme in 82% of total trials. However, only 30% of the trials were solved with an accompanying aha experience. In the Mooney condition, participants reported resolving the solution 67% of all the Mooney trials. Of these, 29% of the Mooney trials were solved with aha experiences. When comparing trials in which internet memes were solved with or without aha (Table 3.4), we found that memes with Aha moments were liked ($t(21) = 4.49$, $p < 0.001$) and understood more than those without ($t(21) = 3.87$, $p < 0.001$). Similarly, aha moments increased participants' liking ($t(18) = 8.03$, $p < 0.001$) and understanding of Mooney images ($t(18) = 3.87$, $p < 0.001$). For Mooney images, aha moments also led to greater ease of processing ($t(18) = 7.22$, $p < 0.001$) and shorter dwell times , ($t(18) = -6.52$, $p < 0.001$). However, this increase in ease of processing and decrease in dwell times were not observed for internet memes. For further analyses on solved and unsolved trials, see Appendix B.

| Measure | Condition | Mean | SD |
|---|---|---|---|
| Internet Memes | | | |
| Liking | Aha | 7.28 | 1.40 |
| | No-Aha | 5.48 | 1.31 |
| Understanding | Aha | 8.37 | 1.34 |
| | No-Aha | 6.95 | 1.47 |
| Mooney Images | | | |
| Liking | Aha | 6.84 | 1.40 |
| | No-Aha | 4.23 | 1.49 |
| Understanding | Aha | 6.75 | 1.35 |
| | No-Aha | 3.34 | 1.14 |
| Ease of Processing | Aha | 6.14 | 1.46 |
| | No-Aha | 3.39 | 1.28 |

| | | | |
|---|---|---|---|
| Dwell Time (sec) | Aha | 22.67 | 15.13 |
| | No-Aha | 36.74 | 21.89 |

***Table 3.4:*** *Effects of Aha Moments on Liking, Understanding, Ease of Processing, and Dwell Times*

*3.7.4 Physiological Response at the Moment of Resolution*

To understand how physiology changes at the moment of resolution, we fit six piecewise growth curve models for zygomatic, corrugator, and skin conductance response for the meme and Mooney conditions.

3.7.4.1 Zygomatic Activity

Regarding zygomatic activity for memes (Figure 3.6), the intercept representing the estimated zygomatic activity at Time = -4000 ms was significantly negative ($b$ = -1.21, $SE$ = 0.03, $t$(7344) = -43.87, $p$ < .001). The first significant increase in zygomatic activity occurred at Time = -3000 ms ($b$ = 0.16, $SE$ = 0.04, $t$(7344) = 4.23, $p$ < .001), and the maximum significant increase was observed at Time = 0 ms (moment of resolution), where activity peaked ($b$ = 1.91, $SE$ = 0.04, $t$(7344) = 48.98, $p$ < .001). After resolution, the first noticeable change occurred at Time = 500 ms ($b$ = 1.98, $SE$ = 0.04, $t$(7344) = 50.89, $p$ < .001), where activity remained elevated but showed a slight decline over time. Overall, the results show a sharp increase in zygomatic activity leading up to resolution, followed by a steady decrease but sustained elevation after the closure.

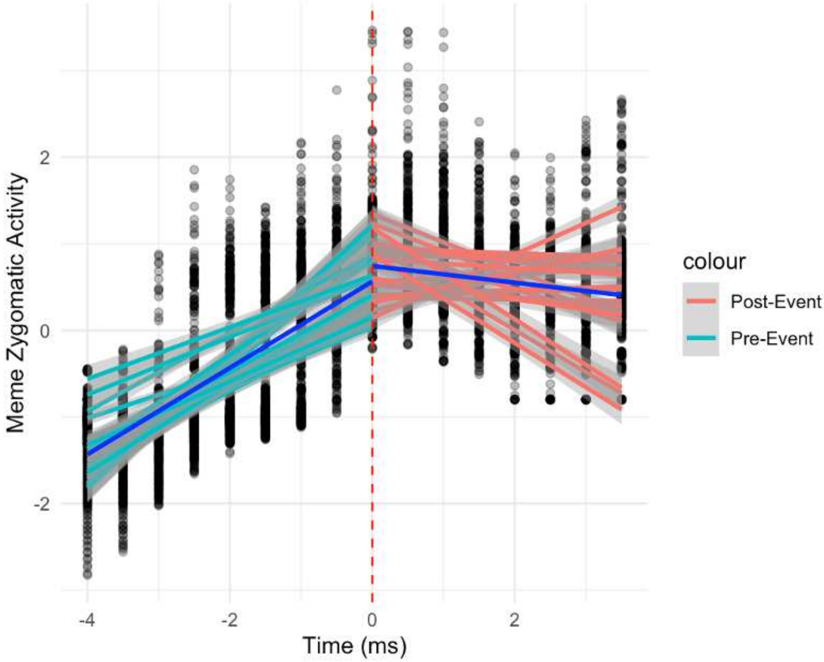


***Figure 3.6:*** *Zygomatic activity before and after moment of resolution for internet memes. Note: Green lines depict individual slopes for participants before the moment of resolution, red lines depict individual slopes after the moment of resolution while the blue line depicts the average slope.*

For the Mooney images (Figure 3.7), zygomatic activity for intercept at Time = -4000 ms was significantly negative ($b$ = -1.22, $SE$ = 0.03, $t$(7120) = -46.06, $p$ < .001). The first significant increase in zygomatic activity was observed at Time = -2500 ms ($b$ = 0.28, $SE$ = 0.04, $t$(7120) = 7.47, $p$ < .001). The maximum increase occurred at Time = 0 ($b$ = 1.88, $SE$ = 0.04, $t$(7120) = 50.29, $p$ < .001). After resolution, there was a slight decrease in zygomatic activity, with a notable decline at Time = 3000 ms ($b$ = 1.68, $SE$ = 0.04, $t$(7120) = 44.90, $p$ < .001), though activity remained positive compared to the reference time point. Overall, zygomatic activity sharply increased leading up to Time = 0, peaked at resolution, and then slightly declined afterward.

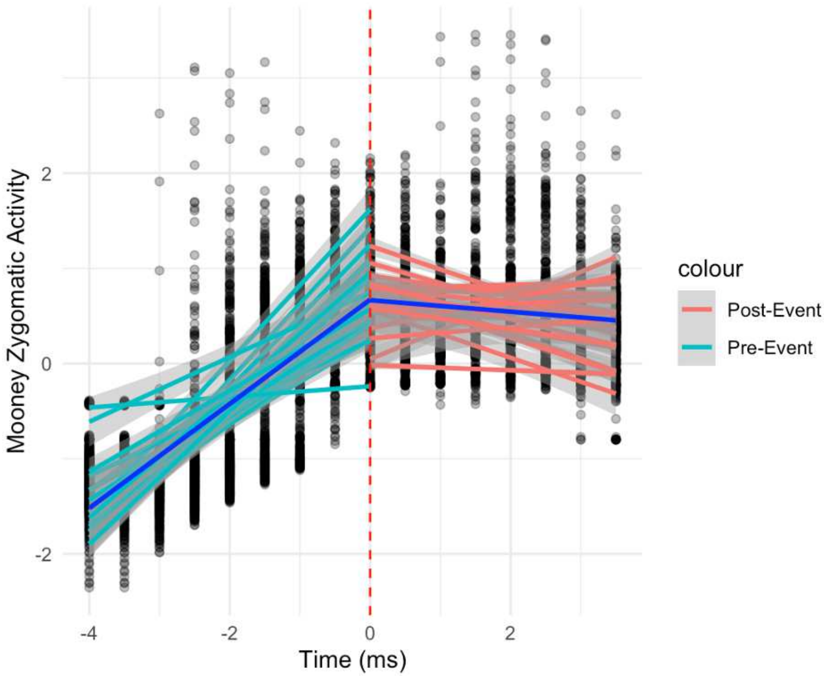


***Figure 3.7:*** *Zygomatic activity before and after moment of resolution for Mooney images.*

3.7.4.2 Corrugator Activity

For internet memes (Figure 3.8), corrugator activity at the intercept Time = -4000 ms was significantly negative ($b$ = -1.39, $SE$ = 0.02, $t$(7344) = -57.36, $p < .001$). The first significant increase in corrugator activity was observed at Time = -2500 ms ($b$ = 0.54, $SE$ = 0.03, $t$(7344) = 15.66, $p < .001$). The maximum increase occurred at Time = 0 ms ($b$ = 2.00, $SE$ = 0.03, $t$(7344) = 58.47, $p < .001$). After resolution, there was a slight increase in activity, with a notable peak at Time = 3500 ms ($b$ = 2.14, $SE$ = 0.03, $t$(7344) = 62.51, $p < .001$), with activity maintaining high levels post-resolution. Overall, corrugator activity increased consistently from Time = -2500 ms and peaked at Time = 0 ms, staying elevated afterward.

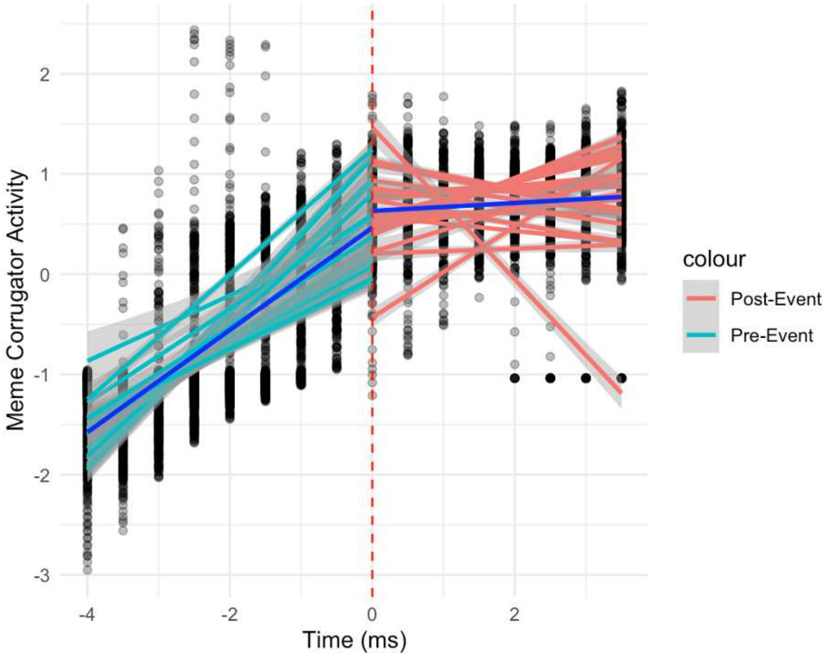


***Figure 3.8:*** *Corrugator activity before and after moment of resolution for internet memes.*

For Mooney images (Figure 3.9), corrugator activity at the intercept Time = -4000 ms was significantly negative ($b$ = -1.22, $SE$ = 0.03, $t$(7136) = -46.06, $p < .001$). The first significant increase in corrugator activity was observed at Time = -2500 ms ($b$ = 0.28, $SE$ = 0.03, $t$(7136) = 7.47, $p < .001$). The maximum increase occurred at Time = 0 ms ($b$ = 1.88, $SE$ = 0.03, $t$(7136) = 50.29, $p <$ .001). After resolution, there was a slight decrease in activity, with activity remaining elevated through Time = 3500 ms ($b$ = 1.58, $SE$ = 0.03, $t$(7136) = 42.30, $p < .001$). Overall, similar to memes, corrugator activity increased consistently from Time = -2500 ms and peaked at Time = 0 ms, maintaining a high level even after resolution.

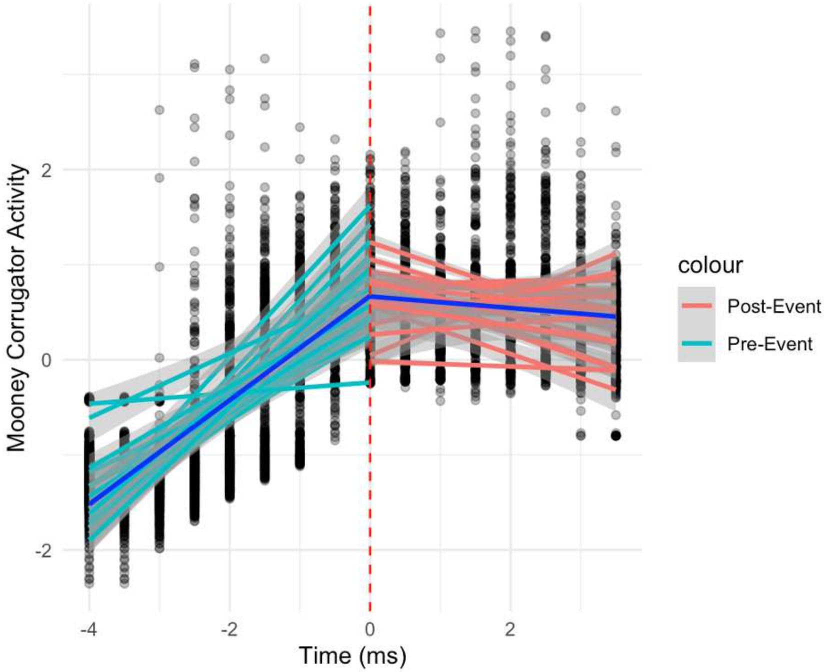


***Figure 3.9:*** *Corrugator activity before and after moment of resolution for Mooney images.*

3.7.4.3 SCR Activity

For internet memes (Figure 3.10), SCR activity at the intercept Time = -4000 ms was significantly positive ($b$ = 0.84, $SE$ = 0.10, $t(2575)$ = 8.07, $p < .001$). The first significant increase in SCR was observed at Time = -500 ms ($b$ = 0.08, $SE$ = 0.04, $t(6663)$ = 2.15, $p <$ 0.05). SCR activity continued to increase significantly with the largest peak observed at Time = 3500 ms ($b$ = 0.16, $SE$ = 0.04, $t(6663)$ = 4.23, $p < .001$). This indicates a progressive increase in SCR activity, starting at 500 ms before the moment of resolution and a continuing rise in SCR activity.

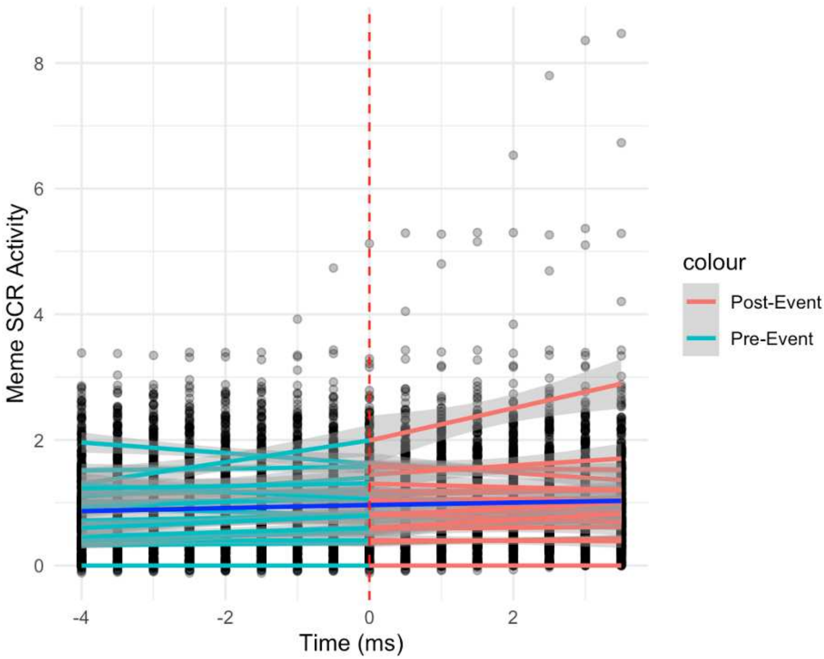


***Figure 3.10:*** *Skin conductance response activity before and after moment of resolution for internet memes.*

For Mooney images (Figure 3.11), the intercept at Time = -4000 ms, which was significantly positive ($b = 1.25$, $SE = 0.27$, $t(27) = 4.54$, $p < .001$). However, no significant changes in SCR activity were observed at any of the subsequent time points (all $p > 0.05$), indicating no systematic SCR response to the Mooney images across the time points measured. The random effects analysis revealed that individual participants accounted for substantial variability in SCR responses ($\sigma^2 = 1.43$, $SE = 1.20$), indicating that participant differences, such as baseline physiological activity or sensitivity to the images, were a major source of variability. The stimuli (Mooney images) contributed relatively less to the variability ($\sigma^2 = 0.24$, $SE = 0.49$), suggesting that the stimuli themselves did not drive significant changes in SCR activity. The residual variance ($\sigma^2 = 3.18$, $SE = 1.78$) indicated that there was considerable unexplained noise in the data, which may have obscured any potential effects of the Mooney images on SCR.

Overall, while the model showed a positive baseline SCR response at Time = -4, the high variability at the participant level and residual noise may have masked any systematic effects across the time points.

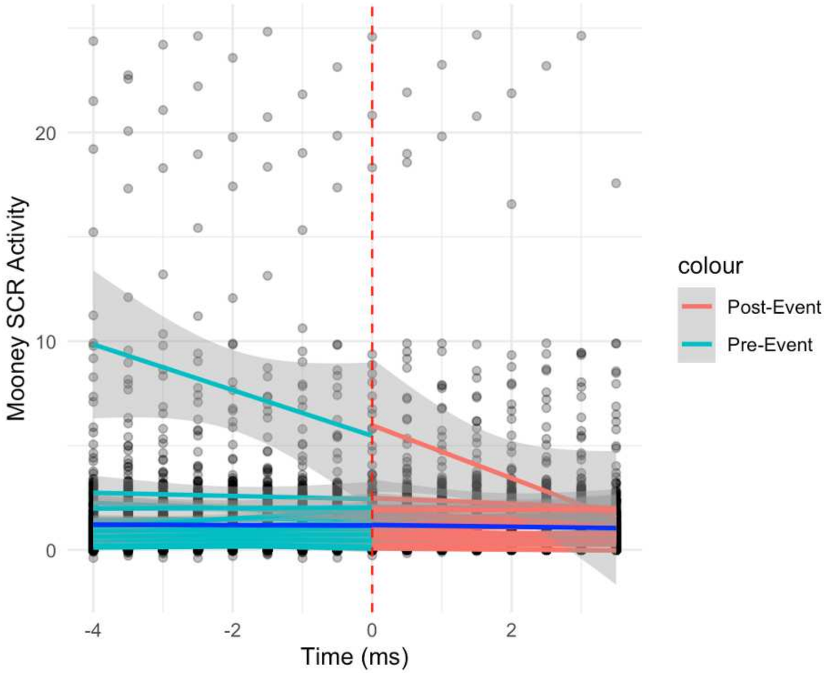


***Figure 3.11:*** *Skin conductance response activity before and after moment of resolution for internet memes. Note: SCR values are continuous but with great variations between participants.*

**3.8 Discussion:**

The results of Experiment 2 further support the role of processing fluency in shaping subjective evaluations and physiological responses to stimuli, mirroring findings from Experiment 1. Overall, we found that memes were processed with greater fluency than Mooney images based on ratings of understanding, ease, liking, and dwell times. In the meme condition, fluency effects were robust, as reflected in higher ratings of liking, understanding, and ease of processing, along with faster dwell times. This aligns with the processing fluency literature, which suggests that fluent stimuli require less cognitive effort, leading to more positive affective and cognitive evaluations (Reber et al., 2004). The negative correlation between SCR magnitude and subjective ratings (liking, ease, understanding) further highlight this effect, suggesting that disfluent memes elicit heightened physiological arousal. Additionally, disfluent memes showed delayed SCR latencies, suggesting prolonged cognitive engagement when resolving harder-to-process content. Similarly, correlations for Mooney images exhibited fluency patterns. Mooney images that were easier to process and understood more were liked more. However, unlike memes, SCR magnitude was positively correlated with liking, ease, and understanding. Still, the latency of SCR magnitude has a negative correlation with liking, ease, and understanding. This suggests that, for Mooney images, the intensity of arousal increases fluency and liking but only if it is elicited earlier in the processing. Furthermore, we found that semantic entropy is not a direct proxy for processing fluency.

Consistent with Experiment 1, we found no significant differences in mean facial EMG activity between fluent and disfluent conditions. However, temporal analyses revealed distinct patterns in physiological response timing. For memes, both zygomatic and corrugator peak latencies were significantly shorter for fluent compared to disfluent memes. Winkielman and Cacioppo (2001) posit that processing fluency produces immediate affective consequences, typically manifesting as positive affect for fluent stimuli and reduced positive or neutral affect for disfluent stimuli. However, our results show that fluency may not merely shape the valence (i.e., positive vs. negative) of affective responses but also their timing—that is, fluency may influence when emotional reactions emerge rather than just how pleasant or unpleasant they are. Fluent stimuli are processed with minimal cognitive effort, leading to early affective responses. In fact, zygomatic activity for memes–which were more fluent than Mooneys–began increasing well before resolution (at -3000 ms), peaked at closure (0 ms), and remained elevated post-resolution, suggesting that fluency generates anticipatory pleasure (Winkielman et al., 2003). For Mooney images, zygomatic responses occurred later (at -2500 ms) and declined more sharply post-closure, reflecting a more transient nature of insight-driven affect for ambiguous stimuli. The corrugator response followed a similar pattern, with early increases for memes (at -2500 ms) and prolonged post-closure activation, potentially indicating lingering cognitive engagement or slower muscular recovery. Additionally, at the moment of resolution, memes elicited a significant increase in SCR 500 ms before the moment of resolution, suggesting a strong autonomic response tied to the resolution of meaning or humor. In contrast, Mooney images did not show significant SCR changes at resolution, highlighting the greater individual variability in response to ambiguous stimuli.

Lastly, aha experiences were infrequent but enhanced liking and understanding for both memes and Mooney images. However, their effects on processing ease and dwell times differed by stimulus type. For Mooney images, aha moments reduced dwell times and increased ease ratings, consistent with insight research showing that sudden perceptual clarity streamlines processing (Topolinski & Reber, 2010). In contrast, for memes, aha moments did not alter processing ease, likely because their inherent familiarity already facilitates fluent processing. This suggests that insight functions differently across stimulus types: for ambiguous stimuli, it resolves perceptual-cognitive conflict, whereas for memes, it may reflect the retrieval of pre-existing knowledge rather than novel problem-solving (Kahneman & Klein, 2009).

### 3.9 General Discussion

These two studies, to the best of our knowledge, are the first to explore the differences in psychophysiological responses to internet memes. Replicating findings from Study 1, we found consistent behavioral differences in the perception and ratings of processing fluency in internet memes. We found that fluent memes were easier to understand, faster to process, and liked more than disfluent internet memes. This aligns with previous research indicating that fluency leads to more positive evaluations and increased liking (Ayele et al., 2025; Reber et. al, 1998, Winkielman & Cacioppo, 2001, see Reber. et. al, 2004). However, we found that these ratings were not significantly influenced by personality traits like need for cognition nor need for cognitive closure. Interestingly, despite the behavioral fluency effects observed, familiarity with memes in general was found to influence processing dynamics but not liking. In Experiment 1, familiarity with memes reduced dwell times, suggesting that increased exposure facilitates faster processing, but it did not necessarily enhance aesthetic enjoyment. This suggests that while familiarity increases fluency, it does not always lead to greater positive affect. This corroborates findings from Study 1 that showed novelty is a key ingredient in the liking of internet memes.

Unlike previous research on processing fluency and facial EMG (Gerger et al., 2011; Topolinski et al., 2009, 2015; Winkielman et al., 2015), we did not observe significant differences in facial EMG activity due to processing fluency. Neither zygomatic nor corrugator facial muscles indicated increased positive or negative emotions due to the processing fluency manipulation. Instead, we find consistent temporal differences across the two experiments. Fluent memes, both in Experiment 1 and Experiment 2, were associated with increased peak frequencies and faster peak latencies in facial EMG responses. Similar to the study on facial mimicry in autism (Oberman et al., 2009), we find differences in peak latencies without finding differences in EMG amplitude. This pattern suggests that processing fluency accelerates the timing—though not necessarily the intensity—of facial muscle responses. Both disfluent memes and Mooney images, compared to memes, had longer maximum peak latencies in facial EMG and SCR responses, indicating that disfluency requires more prolonged cognitive engagement due to greater processing difficulty. For Mooney images, the delayed SCR latencies were negatively correlated with liking and ease ratings, further suggesting that slower physiological responses to ambiguous stimuli were associated with lower subjective fluency and enjoyment.

Regarding skin conductance, we first observed a greater level of arousal in disfluent internet memes compared to fluent internet memes. We also observed a negative correlation of magnitude of arousal with liking and ease of processing. A similar trend was observed in the second experiment, although not replicated significantly when comparing fluency conditions. Disfluent internet memes are often more incongruous and require greater cognitive effort to resolve. This increase in arousal when viewing disfluent internet memes could reflect an increase in arousal in interacting with difficult incongruent stimuli (Noseworthy et al., 2014).

Furthermore, we found several temporal differences at the moment of resolution. For internet memes, we observed that the zygomatic activity increased well before resolution, with a peak at the moment of closure, followed by a return to baseline. This pattern suggests that fluency may elicit anticipatory pleasure, with the zygomatic muscle responding to the ease of processing even before full comprehension is achieved (Winkielman et al., 2003). In contrast, Mooney images showed a more delayed zygomatic response and a less pronounced post-closure recovery, reflecting a more transient emotional response tied to the resolution of ambiguity. Moreover, the SCR responses for memes showed a significant increase 500 ms before resolution, further reinforcing the role of autonomic arousal in processing fluent stimuli. Mooney images did not show similar SCR changes, likely due to the greater individual variability in responses to these more ambiguous stimuli. These were general trends with no significant influence of processing fluency or aha experiences.

These two experiments are subject to several limitations that should be acknowledged. First, we unexpectedly had to remove three participants from the skin conductance analysis in the second experiment due to equipment recording challenges and large errors. This unforeseen loss could have affected the power of our study and our ability to detect significant differences in the magnitude of skin conductance response. While our results were approaching significance, it’s difficult to say whether the results would be replicated with the additional participants. Second, the fluency in the Mooney condition was determined by the semantic entropy variable introduced by Van de Crus et al 2021. However, the stimuli were reportedly extremely difficult, even in the supposedly ‘fluent’ condition. So, we did not successfully manipulate fluency for Mooney images in the experiment as we set out to do. We were still able to carry out an analysis between internet memes and Mooney images. However, future research could use the semantic entropy measures along with a visual inspection to better classify fluent Mooney images from disfluent ones.

Additionally, in Experiment 2, we found that zygomatic and corrugator muscles had a weak but significant positive correlation. This is an unusual finding in the facial EMG literature as they each typically indicate positive and negative emotions respectively (Dimberg, 1982; Larsen et. al, 2003). Zygomatic and corrugator muscular areas traditionally detect positive and negative emotions, respectively. The weak correlation between the two signals suggests either mixed emotions due to humor and ambiguity or crosstalk (Talib et. al, 2019) from the frontalis muscle. Therefore, future research should also measure this muscle and include self-reports of emotions for comparison to EMG findings. Future lines of research could also further incorporate other physiological measures like eye-tracking to investigate how fluency affects gaze and visual attention in internet memes. Also, EEG could offer further interesting information about brain activity during the moment of understanding between fluent and disfluent stimuli. EEG provides excellent temporal resolution that could detect when and where brain activity is happening when processing internet memes.

Our psychophysiological experiments showed that processing fluency has a significant effect on the cognitive and emotional processing of internet memes. Processing fluency, characterized by faster dwell times, higher levels of understanding, and ease of processing for memes and Mooneys and increases the liking of internet memes. Aha moments also increased the liking and understanding of both internet memes and Mooneys. Aha moments are indeed pleasurable experiences that facilitate understanding and aesthetic liking. Further, they increase the ease and dwell times of Mooneys, exhibiting fluency features in an otherwise disfluent stimulus. This further adds to the idea that aha moments are sudden increases in processing fluency (Skaar & Reber, 2020; Topolinski & Reber, 2010 ).

However, unlike previous findings in the processing fluency literature (Gerger et al., 2011; Topolinski et al., 2009, 2015;

Winkielman et al., 2015), we did not observe that fluent stimuli had greater activations of zygomatic facial muscles and lower activations of corrugator muscles. Instead, we find that processing fluency is evidenced in the temporal differences between fluent and disfluent stimuli. Fluent stimuli have faster and more activations of zygomatic and corrugator facial muscles. We also showed the physiological dynamics around the moment of resolution, with fast activations of the corrugator and zygomatic muscles and skin conductance response trailing behind. Trends in skin conductance across participants observed higher levels of arousal for disfluent memes compared to fluent ones, which is likely tracking greater incongruity and a mismatch in expected fluency. In conclusion, we found that processing fluency does not only speed up cognitive processing, but it also increases the speed of affective processing.

## Chapter 4

## The Fluency Effect in Visual Attention: From Exploration to Exploitation

### 4.1 Introduction

Eye-tracking is a powerful tool in cognitive psychology to study mechanisms such as attention, memory, language, and problem solving (Blair et. al, 2009; Chan et. al, 2022, Conklin & Pellicer-Sanchez, 2016, Lee & Ahn, 2014, Susac et. al, 2019, Tsai et. al, 2012). Eye-tracking measures can serve as indices of cognitive load and processing difficulty for various visual and non-visual stimuli. There are three main metrics in eye-tracking: fixations, saccades, and pupil dilation, each providing unique insights into how visual attention is allocated to stimuli. Fixations are periods during which the eyes remain relatively stationary, focusing on a specific location. For example, in scene perception, longer fixation durations can indicate deeper cognitive processing of complex or unexpected elements within a scene (Rayner, 1998). In reading, fixation patterns can reveal processing difficulties, such as longer fixations on rare or complex words (Rayner, 1998). Saccades are rapid eye movements between fixations. The distance travelled from one fixation to another is called saccade amplitude, usually measured by visual degrees. Saccadic movements can also be indicative of cognitive load. Research indicates that increased task difficulty leads to changes in saccadic behavior, such as variations in rate and amplitude, reflecting the brain's effort to process complex information (Phillips & Edelman, 2008, Zelinksy & Shienberg, 1997).

Pupillometry, the measurement of pupil size and reactivity, is another physiological measure used as a window into the brain during cognitive and emotional processing. The pupils of the eyes dilate, or grow larger, not only in response to light but also cognitive load and emotional arousal (Laeng et. al, 2012). For example, early studies into pupil dilation showed that pupils dilate when mental activity increases during problem solving (Hess & Polt, 1964,) and when looking at images of interest (Hess & Polt, 1960). Pupillary dilation has since been linked to the noradrenergic (NE) system's locus coeruleus (LC), a nucleus in the brainstem that is the principal site for brain synthesis of norepinephrine. The LC-NE system modulates various functions, including arousal, attention, and stress responses (Laeng et. al, 2012). Activation of the LC leads to increased norepinephrine release, which in turn influences pupil dilation. This relationship allows pupillometry to serve as a non-invasive proxy for assessing LC activity, providing insights into the neural mechanisms underlying cognitive and emotional processes.

Beyond its role in cognitive load and arousal, the LC-NE system has also been implicated in regulating attentional strategies through the exploration–exploitation trade-off (Hayes & Petrov, 2016, Jepma & Nieuwenhuis, 2011). Attention operates in two complementary modes that help individuals navigate and interpret their environment: exploration and exploitation. In the exploratory mode, attention is directed toward novel or uncertain aspects of the environment, promoting a broad search for new information and enabling the detection of unexpected stimuli. This approach is essential for learning about new environments and forming initial impressions. Conversely, the exploitative mode involves focusing attention on familiar and relevant stimuli to maximize the use of known information. In this state, attention is more concentrated, allowing for deeper processing of selected items. This mode is better for tasks requiring detailed analysis of known elements, such as problem-solving based on existing knowledge. For example, a recent study shows that exploitation modes often lead to longer fixations durations since when only familiar stimuli are present, viewers tend to fixate longer due to reduced exploratory behavior (Nahari et. al, 2024). These two modes of visual attention could help us understand what is happening when people are looking at ambiguous stimuli of varying processing fluency like internet memes and Mooney images.

Internet memes are inherently multimodal which affect how information is integrated. Studies on multimodal perception have shown differing evidence regarding how individuals process and integrate information from visual and textual sources. In some contexts, images seem to capture more attention than text, while in other situations, the text takes precedence. For example, research by Rayner et. al (2001) demonstrated that when both text and images are presented in advertisements, participants tend to fixate more on the images than the text. This suggests that visual stimuli, particularly in advertisements, often grab attention more effectively, potentially because they convey key messages in a more immediate and engaging manner. Conversely, Rayner et. al (2008) found that the viewer's goal plays a significant role in whether attention is directed to the text or the image. In the second study, they observed that when the viewer's goal was to understand the message of the advertisement, they spent more time looking at the text. However, when the goal was to appreciate the visual aesthetics of the advertisement, viewers focused more on the image. These studies show that the integration of visual and textual information is not straightforward and depends on both the content of the stimuli and the viewer's cognitive goals.

Furthermore, studies have shown humor plays a significant role in how we process and attend to information. A study on verbal humor examined how incongruity in verbal humor impacts eye movements (Israel et. al, 2022). They found that humor leads to longer fixation durations, but also more frequent saccades as participants work to resolve the punchline's incongruity. These increased saccadic movements reflect the cognitive effort required to process and integrate the joke's meaning. On the other hand, another study also found that humor can reduce cognitive load by facilitating faster processing (Zheng & Wang, 2023). Participants who rated humorous sentences as funnier exhibited quicker reading times and fewer fixations, suggesting that humor helps streamline cognitive processing and leads to more efficient visual exploration of the text. In regard to multimodal humor, a study on cartoon with both text and image information found that humorous elements in these formats resulted in significantly longer fixation durations, suggesting that humor demands more cognitive resources to process (Carroll et. al, 1992). In addition to prolonged fixations, participants also made more frequent fixations on the humorous content, indicating that viewers were revisiting the humor multiple times to process it fully.

Surprisingly, there is relatively little research on visual attention and Mooney images. Schwiedrzik et. al (2018) and Hegdé et. al

(2007) are two studies that investigate how Mooney images (see. Figure 3.3), designed to induce perceptual closure, engage visual attention and processing. Schwiedrzik et al. (2018) created an extensive set of over 500 Mooney faces to explore how individuals recognize faces from fragmented stimuli. They found that participants' gaze was systematically directed toward the most salient features of the Mooney images, typically the central regions where face features would be located. Interestingly, the research showed that individuals who had prior experience with Mooney images, through training, were able to identify the images more quickly, as they had learned to focus their attention on the correct areas of the stimuli. The eye-tracking data revealed that individuals with prior experience showed longer fixation durations on key areas of the face, reflecting a more efficient processing strategy. Additionally, the study found that gaze behavior was influenced by the level of perceptual ambiguity: when the images were more ambiguous (e.g., lower contrast), participants tended to make more frequent saccadic movements, indicating a more exploratory mode of visual attention. On the other hand, Hegdé et al. (2007) extended the Mooney images to include full-color versions, examining the role of top-down processes in perceptual closure. Their study found that when the images were shown in color, participants recognized the faces more accurately and with faster response times, highlighting the importance of prior knowledge and cognitive expectations in facilitating face perception. Although this study did not use eye-tracking, their behavioral findings suggest that when clarity is increased, attention is directed more efficiently to the relevant features, which aligns with the eye-tracking patterns observed in the work of Schwiedrzik and colleagues.

### *4.1.1 Study Objectives*

In Study 2 and 3, we measured dwell time by measuring how long participants looked at the stimuli. However, our methods did not allow us to measure where participants were looking and for how long. While eye tracking and fluency has been separately studied extensively in cognitive psychology, the intersection of these two topics has remained undeveloped. Eye-tracking metrics such as number of fixations, fixation duration, saccadic amplitude, and changes in pupil diameter length are promising avenues for quantifying processing fluency, especially for multimodal and ambiguous stimuli like memes and Mooney images. In this study, we examine these metrics alongside behavioral measures to uncover potential patterns in visual attention impacted by fluency. Prior to data collection, we pre-registered hypotheses about behavioral, gaze, and pupil data:

Considering the results from Study 1, 2 and 3, we predicted a similar pattern of behavioral ratings. However, unlike the results of Study 3, we still believed with correct manipulation of fluency, we would observe a processing fluency effect on the ratings of Mooney images as well. Therefore, we had three behavioral hypotheses:

1. Fluent memes and Mooneys will be liked better than disfluent memes and Mooneys.

2. Fluent memes and Mooneys will have higher levels of understanding and will be easier to understand than disfluent memes and Mooneys.

3. Fluent Mooneys will be more correctly identified than disfluent Mooneys.

Based on previous literature on gaze and information processing, we had two novel eye-movement hypothesis:

1. Disfluent memes will have a higher number of fixations compared to fluent memes, including in image and text areas of interest (AOIs).

2. Disfluent memes will have a higher average fixation time compared to fluent memes.

Based on studies on pupillometry, cognitive load and aha experiences, we had two pupil dilation hypotheses:

1. There is a relationship between pupil dilation and strength of aha experience.

2. Disfluent memes and Mooneys will have greater dilations of pupils.

## 4.2 Methods

### *4.2.1 Participants*

We recruited 41 participants using a SONA participant recruitment system and recruitment posters around the University of Oslo Psychology Department. This sample size was not calculated a prior but based on sample sizes of eye-tracking studies of similar complexities. A majority of the participants (N = 30 ) were female and were on average 24 years old (STD = 3.31). All participants were rewarded a 200 NOK gift card for their participation.

### *4.2.2 Stimuli*

Participants were shown 60 stimuli in total. Using the same set of stimuli as in Study 3, they saw 15 fluent memes and 15 disfluent memes. All of the presented memes were multimodal that included texts superimposed on the image. Text areas of interest (AOI) were drawn on the areas of the image that contained only text and image AOIs on areas that only contained images. The size and position of the AOIs depended on the construction of the meme itself. There were no statistically significant differences ($t(29) = -0.51$, $p = 0.21$) in the number of words in fluent and disfluent memes. For the Mooney images, we used a subset of the same stimuli as in Study 3. Participants were presented with 15 low semantic entropy and 15 high semantic entropy Mooneys. Since we found that semantic entropy does not directly map onto fluency, we also conducted a manual visual inspection to ensure a correct manipulation of processing fluency for Mooney images. Because of this further manipulation, we refer to low SE Mooney images as “fluent” and high SE Mooney images as “disfluent” in this study. Furthermore, in this study, the Mooney images were accompanied by a categorical clue from the following selection: person, object, animal, food (Figure 15).

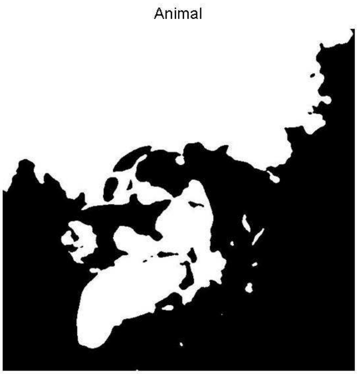


***Figure 4.1:*** *Example of low semantic entropy Mooney stimulus*

*4.2.3 Measures*

Prior to the start of the experiment, participants filled out an online consent form and demographics survey. They were asked their age, gender, and level of familiarity with memes on a 5-point Likert scale of "Not familiar at all" to "Extremely familiar". During the experiment, participants were instructed to press 'a' on the keyboard when they understood the meme or saw the solution to the Mooney image to indicate the moment of resolution. Dwell time was calculated from the stimulus onset to the time participants indicated the moment of resolution. If participants did not indicate a moment of resolution, the length of the entire trial (15 seconds) was used. After the stimulus presentation, participants answered the following questions using the keyboard on a scale from 1-10:

1. How strong was your aha moment?
2. How much did you like this?
3. What was the image of? (Mooney block only)
4. How well did you understand this?
5. How easy was it to process your understanding

6. How curious are you to see the next image?

*4.2.4 Procedure*

After providing consent and demographic information, participants were guided to the experiment room where a Tobii eye-tracking machine was set up in front of a 1920 x 1080 computer screen. Participants were guided to have a comfortable seat about 60 cm from the computer screen with a chin rest to stabilize their head movements during the experiment. Participants were provided with a practice trial in which they were provided definitions for the six measured variables, presented with four practice stimuli with ratings. Once they confirmed their understanding of the experimental tasks, they proceeded with the experiment. Before each stimulus was presented, there was a 300 ms luminosity baseline. This luminosity baseline was used to correct pupil dilation values to remove the effects of ambient light on dilation. Before each stimulus, there was a small fixation circle in the middle of the screen. Then, the stimulus was on the screen for 15 seconds to balance enough time to read and comprehend the memes but control the runtime of the experiment . The meme and Mooney stimuli were presented in counterbalanced blocks. Throughout the experiment, we included four attentional catch trials in which participants were instructed to press a specific key. No participants were removed as they all passed at least 75% of the attentional catch trials.

*4.2.5 Data Analysis*

We used the Tobii Pro Analysis software to automatically preprocess the eye-tracking data into fixations and saccades. After this automatic preprocessing, we exported the data as a csv and further processed it with Python libraries like Pandas and NumPy. We ran paired t-tests using the SciPy Stats library. No outliers were removed from the data as this was not in our pre-registered protocol.

### 4.3 Results

*4.3.1 Behavioral*

In the internet memes condition, participants reported solving the meme in 79% of total trials. For Mooney images, they reported solving the image in 59% of total trials (for further analyses, see Appendix C). When comparing fluent and disfluent internet memes, we found that fluent memes are liked more than disfluent, easier to process, and understood better (Table 4.1). This finding corroborated previous findings from Study 1, 2 and Study 3 about the processing fluency effect on the appreciation of internet memes (Ayele et. al 2025). We also found that fluent internet memes elicited a stronger sense of aha than disfluent memes and elicited higher levels of curiosity. Additionally, in contrast to Study 3, when comparing low semantic entropy (fluent) and high semantic entropy (disfluent) Mooneys, we also found that fluent Mooneys are liked more, easier to process, and better understood (Table 4.2). In addition, we found that fluent Mooney stimuli are more accurately identified compared to disfluent Mooney stimuli). This indicates that Mooney images are influenced by the processing fluency effect, as demonstrated by the manipulation of semantic entropy and visual inspection. However, we did not find any significant differences in curiosity or aha experiences between fluent or disfluent Mooney images.

| **Internet memes** | | | | | |
|---|---|---|---|---|---|
| **Measure** | **Condition** | **Mean** | **SD** | **t(df)** | **p-value** |
| Liking | Fluent | 6.38 | 1.47 | 9.54 (40) | < 0.001 |
| | Disfluent | 4.55 | 1.43 | | |
| Ease of Processing | Fluent | 8.11 | 0.59 | 15.07 (40) | < 0.001 |
| | Disfluent | 5.19 | 1.32 | | |

| | | | | | |
|---|---|---|---|---|---|
| Understanding | Fluent | 8.35 | 0.53 | 17.20 (40) | < 0.001 |
| | Disfluent | 5.06 | 1.74 | | |
| Aha Experience | Fluent | 4.54 | 1.93 | 2.03 (40) | < 0.05 |
| | Disfluent | 3.96 | 1.47 | | |
| Curiosity | Fluent | 6.38 | 1.47 | 2.94 (40) | < 0.01 |
| | Disfluent | 4.55 | 1.43 | | |

***Table 4.1:*** *Behavioral Results for Internet Memes*

| **Mooney Images** | | | | | |
|---|---|---|---|---|---|
| **Measure** | **Condition** | **Mean** | **SD** | **t(df)** | **p-value** |
| Liking | Fluent | 4.50 | 1.28 | 3.42 (40) | 0.01 |
| | Disfluent | 4.20 | 1.25 | | |
| Ease of Processing | Fluent | 4.47 | 1.26 | 5.07 (40) | < 0.001 |
| | Disfluent | 3.97 | 1.24 | | |
| Understanding | Fluent | 4.35 | 1.06 | 5.22 (40) | < 0.001 |
| | Disfluent | 3.88 | 0.99 | | |
| Accuracy (%) | Fluent | 59.00 | 15.00 | 6.04 (40) | < 0.001 |
| | Disfluent | 44.00 | 16.00 | | |

| | | | | | |
|---|---|---|---|---|---|
| Aha Experience | Fluent | 3.73 | 1.38 | 1.51 (40) | 0.14 |
| | Disfluent | 3.60 | 1.37 | | |
| Curiosity | Fluent | 7.15 | 1.80 | -1.39 (40) | 0.17 |
| | Disfluent | 7.34 | 1.68 | | |

***Table 4.2:*** *Behavioral Results for Mooney Images*

### *4.3.2 Fluent and Disfluent Fixations and Saccades*

Looking at fluent memes on average entailed fewer fixations ($t(40) = -6.33$, $p < 0.001$), longer durations of fixations ($t(40) = 3.55$, $p < 0.001$), and shorter saccade amplitudes ($t(40) = 3.19$, $p < 0.01$) compared to disfluent meme viewing. There were no significant differences in pupil diameters for fluent and disfluent memes ($t(40) = -1.54$, $p = 0.13$). This suggests a simple viewing pattern that engages in few elements and does not require as much visual searching as disfluent memes. In contrast, we found no significant differences in the number of fixations ($t(40) = -0.64$, $p = 0.52$), the average duration of fixations ($t(40) = 0.15$, $p = 0.88$), nor pupil dilations ($t(40) = 1.18$, $p = 0.24$) for fluent vs disfluent Mooney images . However, we found that when looking at fluent Mooney images, participants had smaller average saccade amplitudes ($t(40) = -4.95$, $p < 0.001$) compared to disfluent Mooney images. This suggests that while the number and duration of fixations are similar, participants cover greater visual distances when looking at disfluent Mooney images.

| **Internet memes** | | | | | |
|---|---|---|---|---|---|
| **Measure** | **Condition** | **Mean** | **SD** | **t(df)** | **p-value** |
| Number of fixations | Fluent | 39.58 | 5.60 | -6.33(40) | < 0.001 |
| | Disfluent | 42.32 | 5.77 | | |

| | | | | | |
|---|---|---|---|---|---|
| Duration of fixations | Fluent | 289.61 | 49.54 | 3.55 (40) | < 0.001 |
| | Disfluent | 279.68 | 51.42 | | |
| Saccade Amplitude | Fluent | 3.87 | 0.49 | -3.19 (40) | < 0.01 |
| | Disfluent | 4.00 | 0.32 | | |
| Pupil diameter | Fluent | 3.45 | 0.40 | -1.54(40) | 0.13 |
| | Disfluent | 3.48 | 0.40 | | |

***Table 4.3:*** *Fixation and Saccade Results for Internet Memes*

| **Mooney Images** | | | | | |
|---|---|---|---|---|---|
| **Measure** | **Condition** | **Mean** | **SD** | **t(df)** | **p-value** |
| Number of fixations | Fluent | 36.51 | 4.81 | -0.64(40) | 0.52 |
| | Disfluent | 4.20 | 1.25 | | |
| Duration of fixations | Fluent | 324.72 | 53.51 | 0.15 (40) | 0.88 |
| | Disfluent | 324.27 | 48.44 | | |
| Saccade Amplitude | Fluent | 3.76 | 0.62 | -4.95 (40) | < 0.001 |
| | Disfluent | 3.88 | 0.99 | | |
| Pupil diameter | Fluent | 3.45 | 0.40 | -1.54(40) | 0.13 |

| | | | | | |
|---|---|---|---|---|---|
| | Disfluent | 3.48 | 0.40 | 1.18(40) | 0.24 |

***Table 4.4:*** *Fixation and Saccade Results for Mooney Images*

*4.3.3 Text and Image Areas of Interest (AOI)*

When comparing images and text AOIs in the internet memes condition, participants had faster times to first fixation (TTFF) on images ($t(40) = 7.47$, $p < 0.001$) and longer average duration of fixation for images compared to text AOIs ($t(40) = 8.77$, $p < 0.001$). Participants tended to be attracted to images first and for longer periods than texts. When looking at text AOIs, participants had a greater number of total fixations ($t(40) = 4.22$, $p < 0.001$) and saccades ($t(40) = 6.03$, $p < 0.001$) compared to image AOIs. This is consistent with reading behavior instead of scene perception (Rayner, 1998). In the fluent memes condition, participants in the fluent memes condition had faster TTFF ($t(40) = -5.43$, $p < 0.001$), longer average duration of fixations ($t(40) = 2.34$, $p < 0.05$), and fewer number of fixations ($t(40) = -3.11$, $p < 0.01$) on image AOIs compared to disfluent memes. On the other hand, when looking at text AOIs, participants in the fluent memes condition had slower TTFF ($t(40) = 6.09$, $p < 0.001$), longer average duration of fixations ($t(40) = 6.03$, $p < 0.001$), and fewer number of fixations ($t(40) = -2.11$, $p < 0.05$).

| **Internet memes** | | | | | |
|---|---|---|---|---|---|
| **Measure** | **AOI** | **Mean** | **SD** | **t(df)** | **p-value** |
| TTFF | Image | 1471.64 | 282.37 | 7.47(40) | < 0.001 |
| | Text | 1014.06 | 243.41 | | |
| Duration of fixations | Image | 313.43 | 72.87 | 8.77 (40) | < 0.001 |

| | | | | | |
|---|---|---|---|---|---|
| | Text | 247.70 | 34.48 | | |
| Number of fixations | Image | 12.17 | 2.12 | 4.22 (40) | < 0.001 |
| | Text | 14.17 | 2.51 | | |
| Number of saccades | Image | 7.24 | 1.87 | 6.03(40) | < 0.001 |
| | Text | 9.71 | 2.26 | | |

***Table 4.5:*** *Fixation and Saccades in AOIs for internet memes*

### *4.3.4 Category Clue and Target AOIS*

In the Mooney condition, we find that participants have a faster TTFF on the AOIs that contained the category clue compared to the AOIs that contained the target of the image ($t(40) = 6.62$, $p < 0.001$). However, there are more fixations ($t(40) = 46.81$, $p < 0.001$), and longer duration of fixations ($t(40) = 13.66$, $p < 0.001$) in the target AOI compared to the category AOI. When comparing fluent and disfluent Mooneys, we find the same pattern of the results as the overall comparison. Participants had a faster TTFF on the target image AOI for fluent Mooneys compared to disfluent Mooneys ($t(40) = 5.64$, $p < 0.001$). Furthermore, participants had a longer duration of fixations in the target image AOI in fluent conditions than in disfluent conditions ($t(40) = 2.04$, $p < 0.05$) but not in the category AOI condition ($t(40) = 0.33$, $p < 0.73$). Instead, in disfluent Mooney conditions, participants were faster to explore the category AOI ($t(40) = 2.83$, $p < 0.01$). There were no significant differences in the number of fixations when comparing fluent and disfluent Mooney images.

| **Mooney Images** |
|---|

| Measure | Condition | Mean | SD | t(df) | p-value |
|---|---|---|---|---|---|
| TTFF | Category Clue | 210.96 | 88.82 | 6.62 (40) | <0.001 |
| | Target AOI | 1739.21 | 1506.73 | | |
| Duration of fixations | Category Clue | 216.24 | 34.14 | 13.66(40) | < 0.001 |
| | Target AOI | 332.78 | 53.25 | | |
| Number of fixations | Category Clue | 0.96 | 0.58 | 46.81 (40) | < 0.001 |
| | Target AOI | 25.72 | 3.26 | | |
| Number of saccades | Category Clue | 0.06 | 0.07 | 33.48(40) | < 0.001 |
| | Target AOI | 19.08 | 3.63 | | |

***Table 465:*** *Fixation and Saccades in AOIs for Mooney Images*

### *4.4.5 Correlations Between Behavioral and Eye-tracking*

The correlations between behavioral and eye-tracking measures reveal important relationships in both internet memes and Mooney processing. In internet memes (Figure 4.2), there is a positive correlation between liking, curiosity, and strengths of aha experience. This suggests that stimuli that tend to increase the experience of aha also increase liking and curiosity for subsequent stimuli. There is also a strong correlation between understanding and ease of processing, or fluency. However, liking is only significantly correlated with how well the meme was understood, not how easy it was to process. This is understandable since disfluency has been shown to increase liking of memes if it can be resolved. We also found a negative correlation between fluency, understanding, and dwell time. This shows that faster speeds of processing, as evidenced by dwell times, are another signal of processing fluency. Furthermore, dwell times had a positive correlation between number of fixations and negative correlation between average duration of fixation. The longer participants took to arrive at the moment of resolution, the more fixations they made of shorter durations and the lower they reported their level of understanding.

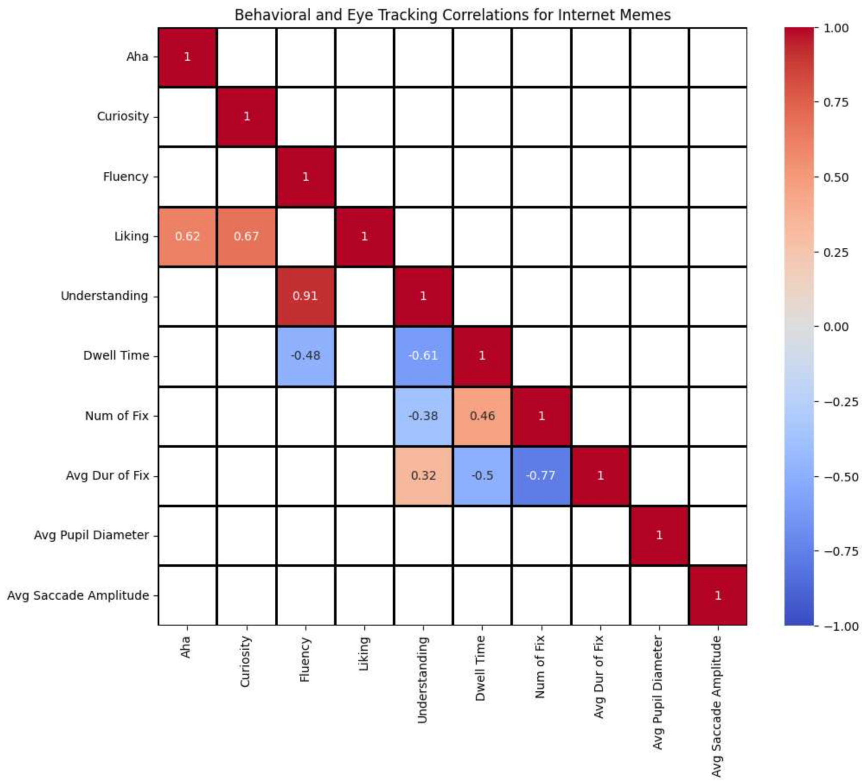


*Figure 4.2: Correlations Between Behavioral and Eye-tracking Measures for Internet Memes*

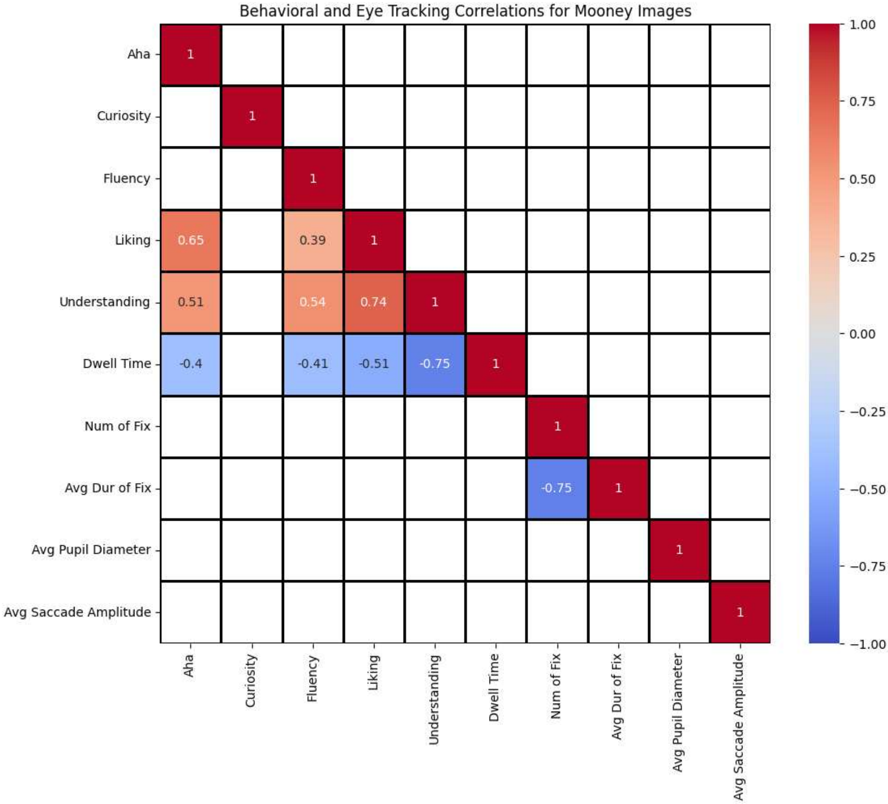


**Figure 4.3:** Correlations Between Behavioral and Eye-tracking Measures for Mooney Images

Meanwhile, Mooney images had a different pattern of correlational relationships (Figure 4.3). Like memes, liking correlates with understanding, aha, and curiosity. However, in Mooneys, liking also correlated with ease of processing, or fluency. Since Mooneys are already disfluent stimuli, ease of processing plays a more significant role in their liking. Strengths of experienced aha for Mooney images also correlated with levels of understanding, faster dwell times, and greater average saccade amplitudes. Like memes, faster dwell times positively correlated with liking, ease of processing, and level of understanding. However, dwell time did not correlate with average duration of fixations nor number of fixations. In fact, while average duration of fixations and number of fixations negatively correlated with each other, they did not significantly correlate with any other measures, behavioral or otherwise.

**4.5 Discussion**

Study 4 examined the impact of processing fluency on preferences and visual attention across two types of ambiguous stimuli: internet memes and Mooney images. Overall, our findings reveal important insights into how visual attention and physiological responses correlate with various measures of processing fluency, curiosity, and understanding across different types of stimuli. Consistent with our hypothesis, our behavioral results once again showed that fluent stimuli, particularly memes, were both liked and understood more easily. Additionally, fluent Mooney images were more accurately identified than disfluent Mooney images. This aligns with Study 1, 2, 3, and previous research that suggests fluency plays a key role in aesthetic judgments (Reber et al., 2004).

Additionally, we found that liking, curiosity, and aha moments were positively interrelated for memes and Mooney images. Memes, being highly multimodal, were also rated as more curious and engaging when fluent. Interestingly, Mooney images showed a significant difference in liking, ease, and level of understanding only for fluent conditions. However, there were no significant differences in curiosity or aha moments between fluent and disfluent Mooney conditions. Still, we observed a significant correlation between aha and reported level of understanding, suggesting that there is a link between participants' experience of aha and their reported understanding of the Mooney image. However, there were no significant correlations with levels of curiosity. When looking at average ratings, participants were generally curious in both Mooney and internet meme conditions. However, encounters with disfluent internet memes significantly lowered curiosity ratings for the following stimuli. This could be because memes require top-down processing, wherein prior knowledge, social norms, or humor frameworks guide interpretation. Viewers approach memes with an expectation of finding them comprehensible and amusing, as they are typically designed to elicit humor. When these expectations are violated by disfluent memes—whether due to obscure references or mismatched visual and textual elements—curiosity and engagement may decrease, as the failure to resolve incongruity undermines the anticipated cognitive reward (Loewenstein, 1994).

Eye-tracking data revealed several key differences in gaze patterns between fluent and disfluent stimuli. Our pre-registered hypotheses were only partially confirmed where disfluent memes have a greater number of fixations. Instead, the data paint a more complex picture than initially expected.  For memes, fluent stimuli were associated with less frequency of fixations of longer durations and shorter saccade amplitudes. Disfluent memes, on the other hand, had the opposite pattern of more fixations of a shorter duration with longer saccade amplitude. These findings fit better with the exploration-exploitation model of attention. Fluent memes elicit an exploitative mode of attention where individuals are less likely to engage in exploratory behavior and more likely to exploit existing knowledge (Nahari et. al, 2024). Disfluent memes elicited an exploratory mode of attention with dispersed attention of shorter durations. On the other hand, Mooney images exhibited a different pattern of gaze behavior. Fluent Mooney images were associated with shorter saccades, but only this measure, and not fixation durations, indicated a significant effect. This suggests that while there may be some differences in the breadth visual exploration in fluent and disfluent Mooney images, the overall patterns of fixations do not differ due to processing fluency.

Interestingly, no significant differences were found in pupil dilation for memes, suggesting that the fluency effect did not significantly influence the level of arousal, as measured by pupil dilation. This is in contrast to the findings of Study 2 that suggested arousal, as measured by SCR magnitude is significantly greater for disfluent memes. There are two potential reasons for this difference in results. One explanation is that SCR is primarily driven by the sympathetic nervous system through the sudomotor nerve pathways (Vetrugno et. al, 2003). Meanwhile, pupillary response is controlled by both the sympathetic (dilator) and parasympathetic (constrictor) nervous system (Laeng et. al, 2012). Therefore, over the course of the stimulus presentation, these two systems could have had opposing influences that leads to overall no significant differences in pupil dilation for fluent and disfluent memes. Another explanation could be that, in the previous experiment, we used SCR magnitude, the strongest response to the stimulus which allowed us to capture the biggest change in arousal. However, in this experiment, we use average change in pupil diameter during the entire stimulus presentation. In addition, unlike our original hypothesis, we found that pupil dilation was not correlated with aha moments in either memes or Mooney images.

Examining areas of interest (AOI) revealed that meme images tended to attract earlier and more attention than text. This is in line with the second study from Rayner et. al (2008) that found when judging aesthetic appeal of multimodal print advertisements, participants tended to focus on images instead of text. Within the text AOIs and image AOIs we find the same pattern of fluent gaze with fewer fixations, longer durations of fixations, and shorter saccades for fluent memes compared to disfluent ones. This further corroborates the exploitation of information in both text and images of fluent memes. On the other hand, Mooney categorical text clue AOIs initially attracted attention before the target image AOI, suggesting that participants needed some priming or cognitive scaffolding to aid top-down processing in perceptual closure (Snodgrass & Feenan, 1990). But, once they received this information, they tended to focus more visual attention to searching for the target AOI in the Mooney. Participants were faster to find the target AOI– the most salient features of the image that contained the person, animal, food, or object–in fluent Mooney conditions compared to disfluent ones. This finding is similar to the study on Mooney faces that showed participants with more familiarity tend to find features that resolve Mooney faces faster (Schwiedrzik et al., 2018).

The correlations between eye-tracking measures and behavioral responses provided further insight into the exploration-exploitation modes of visual attention. In memes, understanding, ease, and dwell times were correlated with a lower number of fixations and longer fixation durations. This is indicative of an exploitative mode of attention that inhibits exploratory behavior in the context of familiar stimuli (Nahari et. al, 2024). The opposite is true of disfluent memes, where more fixations of shorter durations with higher saccade amplitude indicates exploration and visual search behavior. Similarly, for Mooney images, saccade amplitude was positively correlated with aha moments, suggesting that individuals needed to engage in extensive visual exploration to understand the images.

In conclusion, this study demonstrates that processing fluency influences both subjective experience and visual attention. Fluent stimuli, both conceptual and perceptual, were consistently rated as more liked and understood, supporting prior research linking ease of processing to aesthetic judgment. However, curiosity and aha moments were primarily observed for memes, suggesting that the relationship between fluency and insight may be stimulus-dependent, with memes allowing more room for disfluency, expectation violation, and resolution.

Eye-tracking data further revealed that fluency shaped attentional strategies differently across stimulus types. For memes, fluent stimuli led to longer fixation durations, shorter saccades, and decreased fixation counts, consistent with an exploitation mode of attention that promotes focused and sustained engagement with familiar content. In contrast, fluent Mooney images primarily resulted in shorter saccades and faster target recognition, reflecting reduced visual search demands when perceptual coherence is easily established. Correlations between eye-tracking and behavioral measures reinforced these distinctions, as longer fixations and fewer fixations were associated with fluent memes, indicating attentional narrowing, whereas saccade amplitudes in Mooney images correlated with aha moments, suggesting that exploratory search patterns contribute to perceptual insight.

Together, our results suggest that fluency not only influences subjective experience but also systematically alters visual processing strategies, with fluent stimuli promoting efficient, sustained attention and disfluent stimuli encouraging broader search behaviors, particularly in cases requiring perceptual resolution. Future research should explore how these mechanisms extend to more complex visual environments, including content such as video memes, to further uncover the relationship between fluency, attention, and cognitive processing.

## Chapter 5

## General Discussion

This thesis set out to explore whether processing fluency increases the liking of internet memes. Across three studies, different aspects of fluency were examined to understand how it influences the aesthetic, emotional, and cognitive processing of these digital artifacts. The first study provided an exploratory framework for identifying key factors that predict the aesthetic appreciation of internet memes. The second study built on this foundation by investigating the psychophysiological mechanisms underlying fluency and disfluency, using both internet memes and Mooney images. The third study extended these findings by examining gaze patterns associated with fluent and disfluent stimuli. Together, these studies provide a comprehensive understanding of how processing fluency shapes the perception and appreciation of complex visual stimuli in digital culture.

The first study identified five key factors that influence meme appreciation, including humor, fluency, disfluency, positive and negative aesthetic emotions. We found that humor, along with amusement and a lack of boredom, was the most influential factor that predicts the liking of internet memes. Then, a balance of fluency and disfluency was key to the appreciation of memes. Finally, positive emotions like tenderness, adoration, and compassion increased liking while negative emotions like anger, frustration, and sadness decreased liking. Additionally, this study showed that the modality of the memes (family, non-family, text-only, visual-only) did play a significant role in the ratings of memes. Particularly, visual-only memes were extremely disfluent and disliked while family memes tended to be the most fluent. Still, non-family memes, while being slightly disfluent, were liked more than family memes. This further illustrates the delicate balance of fluency and disfluency behind the appreciation of memes.

The second study leveraged the validated stimuli from the first study to investigate the physiological differences of fluent and disfluent stimuli. Behavioral results from both the first and second experiment corroborated the impact of processing fluency on the appreciation of internet memes. Fluent internet memes were rated as more understood, easier to understand, had faster dwell times, and were liked more than disfluent memes. However, these behavioral findings were not accompanied by significant differences in mean EMG activity for neither zygomatic nor corrugator muscles as previous studies would suggest (Gerger et al., 2011; Topolinski et al., 2009, 2015; Winkielman et al., 2015). Instead, we found that fluent memes elicited significantly faster EMG peaks in both muscular areas. While the valence of the affective reactions was not significantly different, the temporal differences suggest that fluency speeds up both cognitive and affective reactions. Additionally, we found significant differences in SCR magnitude that indicates higher levels of arousal for disfluent meme processing compared to fluent memes. However, this result was not replicated in the second experiment. Moreover, in the second study, we introduced Mooney images as a comparison for internet memes. Mooney images were non-humorous perceptual stimuli that contained ambiguity of differing fluency of resolution. We used a measure called "semantic entropy" to serve as a proxy measure of fluency from a previously validated set of Mooney stimuli (Van de Cruys et. al, 2021). However, we found in Study 3 this manipulation did not work. What we considered to be fluent Mooneys were no different behaviorally or physiologically from disfluent ones.

We combat this limitation in the third study by conducting a manual visual inspection to high semantic entropy and low semantic entropy Mooney images. By doing so, we were able to correctly manipulate the fluencies of Mooney images. In the third study, Mooney images were rated similar to memes in that fluent Mooneys were understood more, rated easier to process, had faster dwell times, and were liked more. However, for internet memes, we also found significant differences in ratings of aha and curiosity that we did not observe for Mooney images. In addition to the further confirmation of the processing fluency effect in memes and now Mooney images, we found that fluent memes exhibited different gaze patterns than disfluent memes. Fluent memes had a gaze pattern that indicated a more exploitative pattern of attention. Participants had longer gaze periods with fewer fixations and shorter saccade amplitudes. They tended not focus on particular areas for an extended period of time. Meanwhile, disfluent memes were characterized by an exploratory pattern of attention. Participants made more fixations for shorter durations and with longer saccade amplitudes. This suggests they were searching for meaningful information in effort to resolve the greater disfluency. In Mooney images, fixation patterns did not differ significantly. However, the fluency of the Mooney image did impact how fast participants were able to find the target AOI to resolve the Mooney image. In addition, fluent Mooney images tended to have smaller saccade amplitudes, relatively similar to those of fluent memes.

These results contribute to existing theories of processing fluency by demonstrating its effects in a novel and ecologically relevant domain. While fluency research has traditionally focused on relatively simple stimuli, this thesis shows that its effects extend to complex, culturally embedded digital content. The findings also intersect with theories of information processing, particularly the balance between exploration and exploitation. The idea that fluency leads to a more exploitative gaze, whereas disfluency encourages exploration, offers a new perspective on how cognitive ease influences attentional allocation. Additionally, these results refine previous assumptions about fluency and affect. While past research has emphasized fluency's immediate hedonic benefits, the findings here suggest a more nuanced relationship, where fluency facilitates rapid emotional responses rather than necessarily amplifying positive affect. Moreover, the gaze patterns observed in the third study introduce a potential model for differentiating between fluent and disfluent processing strategies.

The methodological strengths of this research lie in its use of a novel and culturally relevant stimulus set, diverse measurement techniques, and a combination of exploratory and confirmatory approaches. By integrating self-report measures, facial EMG, skin conductance, and eye-tracking, the studies provide a multidimensional perspective on meme processing. However, certain limitations must be acknowledged. One challenge is the inherent subjectivity of fluency, as prior knowledge and personal experience shape what is perceived as fluent or disfluent. Although linear mixed-effects modeling in Study 1 helped account for these individual differences, fluency remains variable across participants. Additionally, the Mooney images used in Study 3 did not elicit strong fluency effects in subjective ratings, limiting their ability to reinforce the broader findings. Though this was rectified in Study 4, the physiological impacts of fluent and disfluent Mooney images are still unknown. Another limitation concerns a larger bias in stimulus selection. As experimenters, we tried to be fair to select stimuli that appealed to a larger population of people. However, we understood all of the memes we selected based on our prior knowledge, this could potentially introduce biases for meme stimuli that we were not familiar with. Furthermore, we used a scale of 1-10 to measure the liking of memes throughout the three studies. While this allowed for consistency and comparability, this may have also constrained response variability. Future studies could address these limitations by implementing a forced-choice paradigm, where participants select the more appealing meme from two options. This approach would not only refine fluency judgments but could also be integrated into reinforcement learning models to further investigate fluency-based decision-making.

Beyond theoretical contributions, these findings have practical implications for fields such as advertising and media literacy. Understanding how fluency influences meme appreciation can inform digital content strategies, helping creators design more engaging and emotionally resonant material. Additionally, these results highlight the importance of media literacy in an era where fluency can shape perceptions of truth and believability. Future research should further investigate the relationship between curiosity, liking, and the “aha” moment to better understand how these cognitive and emotional responses interact. This could involve designing experiments where participants engage with memes that vary in fluency and measure their curiosity-driven behaviors, such as prolonged engagement, revisiting the meme, or actively seeking related content, to determine how curiosity influences liking over time.

Another important direction is exploring the role of active inference and Bayesian models in meme appreciation, which could provide a deeper understanding of how prior expectations shape the perception of fluency and liking. Future studies could manipulate the predictability of memes by systematically varying their familiarity, complexity, or stylistic conventions to observe how the brain updates its internal model in response to surprising or expected content. Tracking neural and behavioral responses in such a paradigm could clarify whether liking emerges from a balance between expected fluency and the reward of resolving uncertainty, offering insights into how cognitive systems adapt to digital media. Neuroimaging methods such as EEG and fMRI could provide deeper insights into the neural mechanisms underlying meme processing, particularly how fluency-related signals emerge and propagate in the brain. EEG could be used to track the temporal dynamics of fluency effects, identifying rapid neural markers of processing ease and emotional engagement. fMRI, on the other hand, could reveal the brain regions involved in fluent versus disfluent meme processing, shedding light on how networks related to reward, semantic processing, and visual perception interact when evaluating digital content. Combining both methods in future studies could offer a more comprehensive understanding of how fluency shapes aesthetic and cognitive responses at both millisecond and whole-brain levels.

At its core, this research underscores the fundamental role of information in human cognition and culture. From ancient storytelling to digital memes, our ability to process and communicate information has shaped the way we understand the world. Internet memes represent a contemporary form of cultural transmission, one that deserves scholarly attention to unravel its cognitive and emotional impact. This thesis contributes to the growing recognition of internet memes as a legitimate subject of empirical aesthetics, bridging psychological theory with digital culture. Looking ahead, these findings pave the way for a new generation of researchers to further explore how the digital age shapes perception, aesthetic preference, and emotions.

# Appendix A

## Chapter 2 Supplementary results

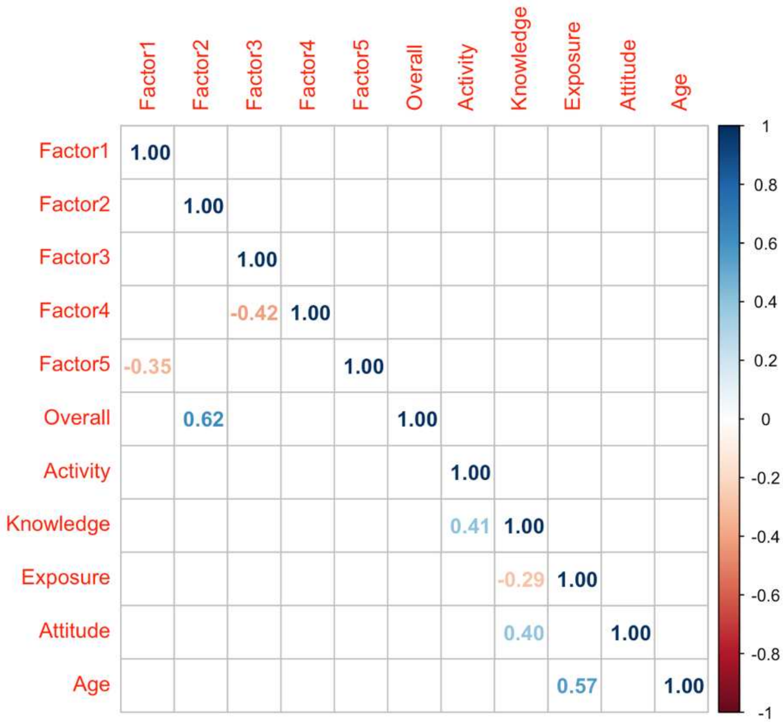


***Figure A.1:*** *Correlational table for Overall liking, Factor 1 (Humor), Factor 2 (Fluency), Factor 3 (Positive Emotions), Factor 4 (Negative Emotions), and Factor 5 (Disfluency) and demographic variables*

| Overall Liking | | | |
|---|---|---|---|
| *Variable* | *β* | *CI* | *p* |
| **(Intercept)** | **2.62** | **1.95 – 3.29** | **<0.001** |
| age | -0.00 | -0.02 – 0.01 | 0.535 |
| Female | 0.06 | -0.07 – 0.20 | 0.379 |
| English fluency | -0.11 | -0.26 – 0.04 | 0.147 |
| activity | -0.01 | -0.08 – 0.07 | 0.893 |
| knowledge | -0.00 | -0.11 – 0.10 | 0.957 |
| exposure | -0.05 | -0.15 – 0.05 | 0.348 |
| **attitude** | **0.14** | **0.01 – 0.27** | **0.029** |
| Observations | | | 4890 |
| Marginal $R^2$ / Conditional $R^2$ | | | 0.007 / 0.302 |

| Humor Factor | | | |
|---|---|---|---|
| *Variable* | *β* | *CI* | *p* |
| (Intercept) | -0.51 | -1.04 – 0.02 | 0.057 |
| age | -0.00 | -0.01 – 0.01 | 0.785 |
| **Female** | **-0.14** | **-0.24 – -0.03** | **0.010** |
| English fluency | 0.06 | -0.06 – 0.17 | 0.354 |
| activity | -0.02 | -0.08 – 0.04 | 0.526 |
| **knowledge** | **0.17** | **0.08 – 0.25** | **<0.001** |
| exposure | -0.01 | -0.08 – 0.07 | 0.896 |
| attitude | 0.02 | -0.08 – 0.12 | 0.744 |
| Observations | | | 4890 |
| Marginal $R^2$ / Conditional $R^2$ | | | 0.024 / 0.516 |

| Fluency Factor | | | |
|---|---|---|---|
| *Variable* | *β* | *CI* | *p* |
| (Intercept) | 0.33 | -0.24 – 0.91 | 0.258 |
| age | -0.01 | -0.02 – 0.00 | 0.085 |
| Female | 0.09 | -0.03 – 0.21 | 0.134 |
| **English fluency** | **-0.15** | **-0.28 – -0.02** | **0.024** |
| activity | -0.02 | -0.09 – 0.05 | 0.567 |
| knowledge | 0.01 | -0.08 – 0.10 | 0.878 |
| exposure | 0.01 | -0.08 – 0.09 | 0.905 |
| attitude | 0.02 | -0.09 – 0.14 | 0.661 |
| Observations | | | 4890 |
| Marginal $R^2$ / Conditional $R^2$ | | | 0.009 / 0.318 |

| Positive Emotions | | | |
|---|---|---|---|
| *Variable* | *β* | *CI* | *p* |
| (Intercept) | 0.00 | -0.45 – 0.45 | 0.993 |
| age | -0.00 | -0.01 – 0.01 | 1.000 |
| Female | 0.00 | -0.09 – 0.09 | 0.960 |
| English fluency | 0.05 | -0.05 – 0.15 | 0.319 |
| activity | -0.00 | -0.06 – 0.05 | 0.906 |
| knowledge | 0.06 | -0.01 – 0.13 | 0.113 |
| exposure | 0.01 | -0.05 – 0.08 | 0.693 |
| attitude | -0.06 | -0.15 – 0.03 | 0.167 |
| Observations | | | 4890 |
| Marginal $R^2$ / Conditional $R^2$ | | | 0.003 / 0.248 |

| Negative Emotions | | | |
|---|---|---|---|
| *Variable* | *β* | *CI* | *p* |
| (Intercept) | -0.49 | -1.02 – 0.04 | 0.069 |
| **age** | **0.01** | **0.00 – 0.02** | **0.035** |
| Female | -0.02 | -0.12 – 0.09 | 0.775 |
| English fluency | 0.08 | -0.04 – 0.20 | 0.205 |
| activity | 0.02 | -0.04 – 0.08 | 0.481 |
| knowledge | -0.03 | -0.11 – 0.06 | 0.524 |
| exposure | -0.01 | -0.09 – 0.07 | 0.818 |
| attitude | 0.03 | -0.07 – 0.13 | 0.582 |
| Observations | | | 4890 |
| Marginal $R^2$ / Conditional $R^2$ | | | 0.007 / 0.292 |

| Disfluency Factor | | | |
|---|---|---|---|
| *Variable* | *β* | *CI* | *p* |
| (Intercept) | 0.26 | -0.71 – 0.18 | 0.246 |
| age | 0.00 | -0.01 – 0.01 | 0.928 |
| Female | 0.02 | -0.07 – 0.11 | 0.628 |
| **English fluency** | **-0.14** | **-0.24 – -0.04** | **0.008** |
| activity | 0.03 | -0.02 – 0.08 | 0.233 |
| **knowledge** | **-0.09** | **-0.16 – -0.02** | **0.014** |
| exposure | 0.04 | -0.03 – 0.10 | 0.266 |
| **attitude** | **0.11** | **0.02 – 0.19** | **0.015** |
| Observations | | | 4890 |
| Marginal $R^2$ / Conditional $R^2$ | | | 0.019 / 0.396 |

***Table A.1:*** *Linear mixed effects model results for Overall liking and factors and demographic predictors.*

| | **Overall Liking** | | |
|---|---|---|---|
| *Predictors* | *Estimates* | *CI* | *p* |
| (Intercept) | 2.72 | 2.61 – 2.83 | **<0.001** |
| Type [Orphan] | 0.20 | 0.06 – 0.35 | **0.006** |
| Type [Text] | 0.16 | -0.02 – 0.34 | 0.075 |
| Type [Visual] | -0.29 | -0.47 – -0.11 | **0.002** |
| **Random Effects** | | | |
| $\sigma^2$ | 1.28 | | |
| $\tau_{00}$ | 0.34 $_{Participant}$ | | |
| | 0.22 $_{Meme}$ | | |
| ICC | 0.31 | | |
| N | 1157 $_{Participant}$ | | |
| | 300 $_{Meme}$ | | |
| Observations | 8094 | | |
| Marginal $R^2$ / Conditional $R^2$ | 0.016 / 0.316 | | |
| | **Humor** | | |
| *Predictors* | *Estimates* | *CI* | *p* |
| (Intercept) | 0.26 | 0.15 – 0.37 | **<0.001** |
| Type [Orphan] | -0.36 | -0.50 – -0.21 | **<0.001** |
| Type [Text] | -0.19 | -0.37 – -0.02 | **0.029** |
| Type [Visual] | -0.92 | -1.10 – -0.75 | **<0.001** |
| **Random Effects** | | | |
| $\sigma^2$ | 0.53 | | |
| $\tau_{00}$ | 0.32 $_{Participant}$ | | |
| | 0.24 $_{Meme}$ | | |
| ICC | 0.51 | | |
| N | 1157 $_{Participant}$ | | |
| | 300 $_{Meme}$ | | |
| Observations | 8094 | | |
| Marginal $R^2$ / Conditional $R^2$ | 0.081 / 0.552 | | |
| | **Fluency** | | |
| *Predictors* | *Estimates* | *CI* | *p* |
| (Intercept) | -0.21 | -0.30 – -0.12 | **<0.001** |
| Type [Orphan] | 0.25 | 0.13 – 0.37 | **<0.001** |

| | | | |
|---|---|---|---|
| Type [Text] | 0.31 | 0.16 – 0.45 | **<0.001** |
| Type [Visual] | 0.24 | 0.10 – 0.39 | **0.001** |
| **Random Effects** | | | |
| $\sigma^2$ | 0.84 | | |
| $\tau_{00}$ | 0.21 $_{Participant}$ | | |
| | 0.15 $_{Meme}$ | | |
| ICC | 0.30 | | |
| N | 1157 $_{Participant}$ | | |
| | 300 $_{Meme}$ | | |
| Observations | 8094 | | |
| Marginal $R^2$ / Conditional $R^2$ | 0.013 / 0.307 | | |
| | **Disfluency** | | |
| *Predictors* | *Estimates* | *CI* | *p* |
| (Intercept) | 0.01 | -0.06 – 0.07 | 0.882 |
| Type [Orphan] | 0.01 | -0.08 – 0.09 | 0.888 |
| Type [Text] | -0.27 | -0.37 – -0.16 | **<0.001** |
| Type [Visual] | 0.22 | 0.11 – 0.33 | **<0.001** |
| **Random Effects** | | | |
| $\sigma^2$ | 0.41 | | |
| $\tau_{00}$ | 0.18 $_{Participant}$ | | |
| | 0.08 $_{Meme}$ | | |
| ICC | 0.39 | | |
| N | 1157 $_{Participant}$ | | |
| | 300 $_{Meme}$ | | |
| Observations | 8094 | | |
| Marginal $R^2$ / Conditional $R^2$ | 0.029 / 0.406 | | |
| | **Positive Emotions** | | |
| *Predictors* | *Estimates* | *CI* | *p* |
| (Intercept) | 0.05 | -0.02 – 0.11 | 0.166 |
| Type [Orphan] | -0.14 | -0.23 – -0.05 | **0.002** |
| Type [Text] | -0.05 | -0.16 – 0.05 | 0.310 |
| Type [Visual] | 0.00 | -0.10 – 0.11 | 0.947 |
| **Random Effects** | | | |
| $\sigma^2$ | 0.62 | | |
| $\tau_{00}$ | 0.18 $_{Participant}$ | | |

| | | | |
|---|---|---|---|
| | 0.07 Meme | | |
| ICC | 0.29 | | |
| N | 1157 Participant | | |
| | 300 Meme | | |
| Observations | 8094 | | |
| Marginal $R^2$ / Conditional $R^2$ | 0.005 / 0.289 | | |
| | **Negative Emotions** | | |
| *Predictors* | *Estimates* | *CI* | *p* |
| (Intercept) | -0.10 | -0.16 – -0.03 | **0.006** |
| Type [Orphan] | 0.21 | 0.13 – 0.30 | **<0.001** |
| Type [Text] | 0.15 | 0.04 – 0.26 | **0.006** |
| Type [Visual] | 0.06 | -0.04 – 0.17 | 0.243 |
| **Random Effects** | | | |
| $\sigma^2$ | 0.63 | | |
| $\tau_{00}$ | 0.17 Participant | | |
| | 0.07 Meme | | |
| ICC | 0.28 | | |
| N | 1157 Participant | | |
| | 300 Meme | | |
| Observations | 8094 | | |
| Marginal $R^2$ / Conditional $R^2$ | 0.009 / 0.289 | | |

Table A.2: Linear mixed effects model results for Overall liking and factors and stimulus modality predictors.

## Appendix B

## Chapter 3 Supplementary results

Internet Memes

| Liking | | | | | | |
|---|---|---|---|---|---|---|
| group1 | group2 | Mean Diff (Group 2 – 1) | p-adj | lower | upper | reject |
| **Solved w/ aha** | **Solved w/o aha** | **-1.132** | **0.0** | **-1.684** | **-0.579** | **True** |
| **Solved w/ aha** | **Unsolved** | **-4.294** | **0.0** | **-5.001** | **-3.587** | **True** |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Solved w/o aha** | **Unsolved** | **-3.162** | **0.0** | **-3.778** | **-2.545** | **True** |
| Ease | | | | | | |
| group1 | group2 | Mean Diff (Group 2 – 1) | p-adj | lower | upper | reject |
| **Solved w/ aha** | **Solved w/o aha** | **0.918** | **0.00** | **0.333** | **1.503** | **True** |
| **Solved w/ aha** | **Unsolved** | **-3.736** | **0.0** | **-4.486** | **-2.987** | **True** |
| **Solved w/o aha** | **Unsolved** | **-4.655** | **0.0** | **-5.308** | **-4.002** | **True** |
| Understanding | | | | | | |
| group1 | group2 | Mean Diff (Group 2 – 1) | p-adj | lower | upper | reject |
| Solved w/ aha | Solved w/o aha | 0.123 | 0.86 | -0.438 | 0.686 | False |
| **Solved w/ aha** | **Unsolved** | **-4.842** | **0.0** | **-5.562** | **-4.1217** | **True** |
| **Solved w/o aha** | **Unsolved** | **-4.966** | **0.0** | **5.594** | **-4.002** | **True** |
| Dwell Time | | | | | | |
| group1 | group2 | meandiff | p-adj | lower | upper | reject |
| Solved w/ aha | Solved w/o aha | -1.368 | 0.42 | -3.940 | 1.204 | False |
| **Solved w/ aha** | **Unsolved** | **10.852** | **0.0** | **7.559** | **14.144** | **True** |
| **Solved w/o aha** | **Unsolved** | **12.220** | **0.0** | **9.349** | **15.090** | **True** |

Table B.1: Tukey HSD results for differences in liking, ease, understanding, and dwell time for internet meme trials that were solved with aha, solved without aha, and unsolved.

Mooney Images

| Liking | | | | | | |
|---|---|---|---|---|---|---|
| Group 1 | Group 2 | Mean Diff (Group 2 – 1) | p-adjusted | upper | lower | reject |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Solved w/aha** | **Solved w/o aha** | **-1.738** | **0.0** | **-2.292** | **-1.185** | **True** |
| **Solved w/ aha** | **Unsolved** | **-4.060** | **0.0** | **-4.650** | **-3.469** | **True** |
| **Solved w/o aha** | **Unsolved** | **-2.321** | **0.0** | **-2.790** | **-1.852** | **True** |
| Ease | | | | | | |
| Group 1 | Group 2 | Mean Diff (Group 2 – 1) | p-adjusted | upper | lower | reject |
| **Solved w/aha** | **Solved w/o aha** | **-1.495** | **0.0** | **-2.032** | **-0.957** | **True** |
| **Solved w/ aha** | **Not solved** | **-4.568** | **0.0** | **-5.142** | **-3.995** | **True** |
| **Solved w/o aha** | **Not solved** | **-3.073** | **0.0** | **-3.528** | **-2.618** | **True** |
| Understanding | | | | | | |
| Group 1 | Group 2 | Mean Diff (Group 2 – 1) | p-adjusted | upper | lower | reject |
| **Solved w/ aha** | **Solved w/o aha** | **-2.012** | **0.0** | **-2.492** | **-1.531** | **True** |
| **Solved w/ aha** | **Not solved** | **-5.136** | **0.0** | **-5.649** | **-4.622** | **True** |
| **Solved w/o aha** | **Not solved** | **-3.124** | **0.0** | **-3.531** | **-2.716** | **True** |
| Dwell Time | | | | | | |
| Group 1 | Group 2 | Mean Diff (Group 2 – 1) | p-adjusted | upper | lower | reject |
| Solved w/ aha | Solved w/o aha | 1.904 | 0.7987 | -5.103 | 8.911 | False |
| **Solved w/ aha** | **Not solved** | **24.966** | **0.0** | **17.485** | **32.447** | **True** |
| **Solved w/o aha** | **Not solved** | **23.062** | **0.0** | **17.127** | **28.998** | **True** |

***Table B.2:*** *Tukey HSD results for differences in liking, ease, understanding, and dwell time for Mooney image trials that were solved with aha, solved without aha, and unsolved.*

Internet Memes

| Zygomatic Mean | | | | | | |
|---|---|---|---|---|---|---|
| Group 1 | Group 2 | Mean Diff (Group 2 – 1) | p-adj | Lower | Upper | Reject |
| **Solved w/ Aha** | **Solved w/o Aha** | **-0.331** | **0.020** | **-0.620** | **-0.041** | **True** |
| Solved w/ Aha | Not solved | -0.301 | 0.123 | -0.662 | 0.060 | False |
| Solved w/o Aha | Not solved | 0.029 | 0.969 | -0.267 | 0.327 | False |
| Corrugator Mean | | | | | | |
| Group 1 | Group 2 | Mean Diff (Group 2 – 1) | p-adj | Lower | Upper | Reject |
| Solved w/ Aha | Solved w/o Aha | -0.052 | 0.901 | -0.339 | 0.233 | False |
| Solved w/ Aha | Not solved | 0.045 | 0.952 | -0.311 | 0.402 | False |
| Solved w/o Aha | Not solved | 0.098 | 0.727 | -0.205 | 0.401 | False |
| SCR Magnitude | | | | | | |
| Group 1 | Group 2 | Mean Diff (Group 2 – 1) | p-adj | Lower | Upper | Reject |
| Solved w/ Aha | Solved w/o Aha | 0.163 | 0.369 | -0.121 | 0.448 | False |
| Solved w/ Aha | Not solved | 0.309 | 0.101 | -0.045 | 0.664 | False |
| Solved w/o Aha | Not solved | 0.145 | 0.488 | -0.154 | 0.445 | False |

Table B.3: Tukey HSD results for differences in zygomatic mean, corrugator mean, and SCR magnitude for internet meme trials that were solved with aha, solved without aha, and unsolved.

Mooney Images

| Zygomatic Mean | | | | | | |
|---|---|---|---|---|---|---|
| Group 1 | Group 2 | Mean Diff (Group 2 – 1) | p-adj | Lower | Upper | Reject |
| Solved w/ Aha | Solved w/o Aha | -0.298 | 0.05 | -0.599 | 0.001 | False |
| Solved w/ Aha | Not solved | 0.013 | 0.99 | -0.311 | 0.338 | False |
| **Solved w/o Aha** | **Not solved** | **0.312** | **0.01** | **0.051** | **0.572** | **True** |
| Corrugator Mean | | | | | | |
| Group 1 | Group 2 | Mean Diff (Group 2 – 1) | p-adj | Lower | Upper | Reject |
| Solved w/ Aha | Solved w/o Aha | 0.076 | 0.84 | -0.246 | 0.398 | False |
| Solved w/ Aha | Not solved | 0.025 | 0.98 | -0.322 | 0.373 | False |
| Solved w/o Aha | Not solved | -0.050 | 0.9 | -0.326 | 0.224 | False |
| SCR Magnitude | | | | | | |
| Group 1 | Group 2 | Mean Diff (Group 2 – 1) | p-adj | Lower | Upper | Reject |
| Solved w/ Aha | Solved w/o Aha | -0.043 | 0.94 | -0.376 | 0.288 | False |
| Solved w/ Aha | Not solved | -0.147 | 0.59 | -0.504 | 0.209 | False |
| Solved w/o Aha | Not solved | -0.103 | 0.65 | -0.384 | 0.177 | False |

***Table B.4:*** *Tukey HSD results for differences in zygomatic mean, corrugator mean, and SCR magnitude for Mooney image trials that were solved with aha, solved without aha, and unsolved.*

## Appendix C

## Supplementary results for Chapter 4

| Internet Memes | | | | | | | |
|---|---|---|---|---|---|---|---|
| Measure | Group 1 | Group 2 | Mean Diff (Group 2 – 1) | p-adj | Lower | Upper | Reject |
| **Liking** | **Solved** | **Not solved** | **-0.408** | **0.03** | **-0.783** | **-0.034** | **True** |
| **Understanding** | **Solved** | **Not solved** | **-1.091** | **0.00** | **-1.499** | **-0.683** | **True** |
| Curiosity | Solved | Not solved | 0.031 | 0.83 | -0.255 | 0.317 | False |
| **Aha** | **Solved** | **Not solved** | **-0.747** | **0.00** | **-1.115** | **-0.380** | **True** |
| Dwell Time | Solved | Not solved | -0.071 | 0.83 | -0.760 | 0.617 | False |
| **Number of Fixations** | **Solved** | **Not solved** | **3.474** | **0.00** | **2.145** | **4.804** | **True** |
| **Fixation Duration (Avg)** | **Solved** | **Not solved** | **-12.74** | **0.03** | **-24.183** | **-1.313** | **True** |
| Saccade Amplitude (Avg) | Solved | Not solved | 0.043 | 0.53 | -0.090 | 0.177 | False |
| Pupil Diameter (Avg) | Solved | Not solved | 0.019 | 0.30 | -0.016 | 0.055 | False |

***Table C.1:*** *Tukey HSD results for differences in liking, understanding, curiosity, aha, dwell time, number of fixations, fixation duration, saccade amplitude, and pupil diameter in solved and unsolved internet memes.*

| Mooney Images | | | | | | | |
|---|---|---|---|---|---|---|---|
| Measure | Group 1 | Group 2 | Mean Diff (Group 2 – 1) | p-adj | Lower | Upper | Reject |
| **Liking** | **Solved** | **Not solved** | **-1.510** | **0.00** | **-2.406** | **-0.614** | **True** |
| **Understanding** | **Solved** | **Not solved** | **-4.007** | **0.00** | **-4.830** | **-3.184** | **True** |
| Curiosity | Solved | Not solved | 0.022 | 0.95 | -0.789 | 0.834 | False |
| **Aha** | **Solved** | **Not solved** | **-4.481** | **0.00** | **-5.101** | **-3.861** | **True** |
| Dwell Time | Solved | Not solved | 0.290 | 0.80 | -1.993 | 2.574 | False |
| **Number of Fixations** | **Solved** | **Not solved** | **5.529** | **0.00** | **2.208** | **8.850** | **True** |
| **Fixation Duration (Avg)** | **Solved** | **Not solved** | **-35.884** | **0.02** | **-66.00** | **-5.764** | **True** |
| Saccade Amplitude (Avg) | Solved | Not solved | 0.187 | 0.45 | -0.311 | 0.6859 | False |
| Pupil Diameter (Avg) | Solved | Not solved | 0.063 | 0.22 | -0.040 | 0.1666 | False |

***Table C.2:*** *Tukey HSD results for differences in liking, understanding, curiosity, aha, dwell time, number of fixations, fixation duration, saccade amplitude, and pupil diameter in solved and unsolved Mooney images.*

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