SULTAN RENGİN DALKIRAN RELATION OF PERCEPTUAL FLUENCY WITH METAMEMORY JUDGMENTS AND RECOGNITION MEMORY Bilkent University 2024

RELATION OF PERCEPTUAL FLUENCY WITH METAMEMORY JUDGMENTS AND RECOGNITION MEMORY

A Master's Thesis

by
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Ankara
May 2024

To my beloved family and friends.

RELATION OF PERCEPTUAL FLUENCY WITH METAMEMORY JUDGMENTS AND RECOGNITION MEMORY

The Graduate School of Economics and Social Sciences
of
İhsan Doğramacı Bilkent University

by

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In Partial Fulfillment of the Requirements for the Degree of
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THE DEPARTMENT OF
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RELATION OF PERCEPTUAL FLUENCY WITH METAMEMORY JUDGMENTS AND RECOGNITION MEMORY
By Sultan Rengin Dalkıran

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Arts in Psychology.

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ABSTRACT

RELATION OF PERCEPTUAL FLUENCY WITH METAMEMORY JUDGMENTS AND RECOGNITION MEMORY

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May 2024

Previous research has shown that perceptual fluency differentially affects metamemory judgments and actual recognition performance. In this sense, the perceptual-fluency hypothesis asserts that fluent items are considered more memorable and are likely to receive higher metamemory judgments than disfluent items, which is replicated in multiple studies. Despite a demonstrated positive effect of perceptual fluency on metamemory judgments, the relationship between perceptual fluency and recognition memory performance is less clear. Therefore, in this study, we aimed to further investigate the distinctive effects of perceptual fluency on metamemory judgments and actual recognition performance for pictures. Respectively, in Experiment 1, subjects (n = 30) were presented with blurred or clear pictures and prompted with judgments of learning (JOLs) ratings at study, followed

by a recognition test. In Experiment 2, our main focus was on the direct association between perceptual fluency and actual recognition performance. Hence, the second experiment was similar to the first one except subjects (n = 48) were not prompted with JOLs and multiple sources of manipulations (blurriness and inversion) were implemented to induce perceptual disfluency. The results showed that neither metamemory judgments nor actual recognition performance significantly differed in response to perceptual fluency. Thus, in contrast to many other studies, the current study failed to support the perceptual fluency hypothesis even though our results about actual recognition performance aligned with past research.

Keywords: Perceptual fluency, metamemory judgments, recognition memory, recollection, familiarity

ÖZET

ALGISAL AKICILIĞIN ÜST-BELLEK YARGILARI VE TANIMA BELLEĞİ İLE İLİŞKİSİ

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Yapılan araştırmalar algısal akıcılığın tanıma belleği ve üst-bellek yargıları üzerine farklı etkileri olduğunu göstermiştir. Bu bağlamda birçok çalışma tarafından da desteklenen algısal akıcılık hipotezi, daha kolay algılanabilen nesnelerin kişilerde daha fazla hatırlanabileceği yargısı oluşturduğunu öne sürmektedir. Yapılan çalışmalar algısal akıcılık ve üst-bellek yargıları arasında genel olarak pozitif bir ilişki olduğunu gösterse de algısal akıcılık ve tanıma belleği performansı arasındaki ilişkiyi inceleyen çalışmaların sonuçları farklılık göstermektedir. Bu nedenle bu çalışmada algısal akıcılığın üst-bellek yargıları ve tanıma belleği performansı üzerindeki etkisi resimler kullanılarak araştırılmıştır. Birinci deneyde deneklere (n = 30) bulanık ve normal resimler gösterilmiş, deneklerden bu resimleri daha sonraki bir bellek testinde hatırlamalarına dair bellek tahminleri öğrenme yargıları (ÖY) ile alınmış, sonrasında ise deneklere bellek testi verilmiştir. İkinci deney ise algısal akıcılık ve tanıma belleği arasındaki direkt ilişkiyi araştırmaktadır. Bu yüzden ikinci deney birinciye benzemesine karşın deneklere (n = 48) bellek tahminlerine ilişkin

öğrenme yargıları sorulmamış ve algısal akıcılık bulanıklığın yanı sıra ters çevirme ile manipüle edilmiştir. Sonuçlar üst-bellek yargıları ve tanıma belleği performansının algısal akıcılık manipülasyonlarından etkilenmediğini göstermiştir. Dolayısıyla algısal akıcılık ve üst-bellek yargıları arasındaki sonuçlar algısal akıcılık hipotezini desteklemese de algısal akıcılık ve tanıma belleği performansı arasındaki sonuçlar geçmiş çalışmaları desteklemektedir.

Anahtar Kelimeler*:* Algısal akıcılık, üst-bellek yargıları, tanıma belleği, hatırlama, aşinalık

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CHAPTER I

INTRODUCTION

Recognition memory has been subject to an ongoing debate about whether it consists of a single continuous process or two distinct processes. In this sense, while single-process models define recognition memory with a single unit, dual accounts of recognition memory argue about the presence of two subsystems (Yonelinas & Levy, 2002).

As mentioned above, initially single-process models suggested that recognition memory depended on a single factor. This factor, termed *familiarity,* was described based on stimulus recency and memory strength (Ingram, Mickes, & Wixted, 2012). Yet familiarity poorly addressed the retrieval of contextual aspects of a study episode. Therefore, dual accounts introduced *recollection* to explain the contextual facets of recognition memory (Ozubko, Moscovitch, & Winocur, 2017).

With decades of work, dual process models have attributed distinct characteristics to familiarity and recollection. One of these cardinal characteristic differences, which is also the focus of this study, is the selective responsivity of familiarity and recollection to perceptual and conceptual manipulations. In this regard, many studies have shown that recollection and

familiarity are influenced by conceptual (or semantic) and perceptual manipulations, respectively (Yonelinas, 2002). In contrast, other studies have reported that recollection and familiarity are indifferently sensitive to both conceptual and perceptual manipulations (Rajaram, 1996; Whittlesea, 1993). Hence, the effects of perceptual and conceptual manipulations on familiarity and recollection are far from conclusion.

Although the impacts of perceptual and conceptual manipulations on recognition memory are equally important, this study was particularly interested in the effects of perceptual manipulations on recognition memory. To this end, we aimed to explore the influence of perceptual processes on both actual recognition memory performance and *metamemory judgments*, which includes a range of heuristics, beliefs and experiential processes to avail memory (Koriat & Helstrup, 2007).

In terms of the effects of perceptual manipulations on metamemory judgments, several theories have been postulated. One theory, however, has attracted substantial attention in recognition memory research. According to this theory, referred to as the *perceptual-fluency hypothesis*, items that are easier to process at encoding are considered more memorable and receive higher metamemory judgments (Hirshman & Mulligan, 1991). In this sense, one common measure of metamemory judgments is the *judgments of learning* (JOLs), defined as the confidence rating about the memorability of an item on a subsequent recognition test (Rhodes, 2016), and studies on this method consistently

supported perceptual-fluency hypothesis (Begg et al., 1989). However, these studies heavily relied on verbal material, and thus, one aim of this study was to elucidate whether these results extended to pictorial material.

Although a positive relationship between perceptual fluency and metamemory judgments has been found in past research, findings about the impact of perceptual fluency on actual recognition performance vary. On one hand, some studies have reported that actual recognition performance remained insensitive to alterations in visual acuity despite a positive association between perceptual fluency and metamemory judgments (Rhodes & Castel, 2008; McDonough & Gallo, 2012). Alternatively, some other studies have demonstrated an improved recognition performance in response to disfluency, which is referred to as *perceptual-interference effect* (Nairne, 1988). Thus, another focus of this study was to address this duality by comparing the recognition memory performances for disfluent and fluent pictures.

1.1. Single-Process Models

Although human memory systems have been studied extensively, their precise nature remains uncovered. Decades of work yielded different models and parts of memory. One such part is the *recognition memory*, which represents the ability to remember (Brown & Aggleton, 2001). Initially, single-process models dominated the recognition memory research. According to these models, a continuous single process relying on Gaussian unequal-variance

signal-detection models governed recognition memory (Ingram, Mickes, & Wixted, 2012). The main assumption was that a greater sense of *familiarity*, defined as item recognition based on stimulus recency and memory strength, was present for studied items than for non-studied items; therefore, familiar items were assumed to be studied (Yonelinas & Levy, 2002). Hence, recognition memory accuracy depended on a single parameter (i.e., the average difference in distribution between old and new items abbreviated with *d'*) in single-process models (Yonelinas, 2001).

Over time, single-process models have become more advanced with the help of additional premises regarding the representation and storage of items in a memory system (Yonelinas, 2001), but the characterization of recognition memory solely with familiarity was incomplete. This was mainly because subjects could also retrieve contextual details of a study episode, which could not be thoroughly explained by familiarity-based recognition (Ozubko, Moscovitch, & Winocur, 2017). Consequently, dual accounts were proposed to address the two-factor theory of recognition memory (Yonelinas, 2001).

1.2. Dual-Process Models

Even though the dual-process models of recognition memory have gathered momentum starting from 1970, their origins date back to Aristotle (Yonelinas, 2002). According to dual-process models, recognition memory is characterized by two subprocesses, 1) familiarity and 2) *recollection*, which is the conscious

reliving of a specific study episode (Yonelinas et al., 2010). One common example of this approach is “the butcher on the bus” phenomenon (Mandler, 1980). In this example, suppose that you bump into someone on the bus who looks familiar to you, but you cannot recall his identity (i.e., familiarity), then you realize that he is the butcher in your neighbourhood (i.e., recollection) (Mandler, 1980; Migo, Mayes, Montaldi, 2012). Therefore, recollection and familiarity differ based on both types of retrieved information (i.e., contextual or item information) (Dimsdale-Zucker et al., 2022) and subjective experience (Leynes and Nagovsky, 2016; Souchay et al., 2013).

One of the earliest pieces of evidence for dual accounts of recognition memory was obtained from behavioural studies on *process-dissociation procedures*. Introduced by Jacoby (1991), the process-dissociation procedure was used to provide a general framework for addressing the differential contributions of automatic and intentional processes into memory, whereby the former and latter processes reflect familiarity and recollection respectively. In a series of experiments, Jacoby (1991) asked subjects to either read normal words or solve anagrams (Experiment 1) or additionally hear and repeat some words (Experiment 2, 3) at study. At test, subjects were assigned to either undivided or divided attention conditions, presented with both studied and non-studied words and asked to indicate whether the prompted word was “old” or “new”. In undivided attention condition, subjects only engaged in the recognition task, while they were simultaneously given a listening task about detecting target

sequences of random digits in divided attention condition. The results of Experiments 1 and 2 consistently showed that intentional processing derived from solving anagrams was significantly impaired in divided attention conditions, whereas familiarity-based responses remained insensitive. Experiment 3, on the other hand, was the first study to demonstrate the process-dissociation method. In this experiment, subjects were given inclusion and exclusion tests, in which they were asked to give “old” responses for both normal and heard words and anagrams in the inclusion test, and only for heard words in the exclusion test. The difference between exclusion and inclusion test performances was described as the measure of conscious control. The results of Experiment 3 also reported that divided attention hindered recollection-based judgments, while leaving familiarity-based judgments intact. Altogether, these findings highlight that familiarity and recollection are two independent processes contributing to recognition memory (Jacoby, 1991).

Moreover, considerable support for behavioural studies comes from statistical evidence. Analysis of hit and false alarm rates in recognition confidence responses have shown that recollection and familiarity display separate receiver operating characteristics (ROCs), which is highlighted by Yonelinas (1994). ROCs are defined as the proportion of correct recognition responses (i.e., hit rate) to the proportion of incorrect recognition responses (i.e., false alarm rate) (Yonelinas & Parks, 2007). In this sense, when hit rates are plotted against false alarm rates (i.e., recognition accuracy), observed empirical

functions display a curvilinear pattern that changes across conditions (Yonelinas, 1994). In some studies, increased ROC asymmetry is observed in response to an increased recognition accuracy (Donaldson & Murdock, 1968; Glanzer & Adams, 1990), while ROC asymmetry remains stable despite an increased recognition accuracy in other studies (Ratcliff, Sheu & Gronlund 1992), meaning that at least two separate memory units underlie recognition memory (Yonelinas, 1994). These findings support the notion that at least two separate processes are needed to point out the differences in statistical characteristics of recognition memory performances.

Another line of evidence for dual-process models arises from neuro-imaging studies. Even though the precise brain regions contributing to recollection and familiarity processes are yet to be deciphered, divergent neural substrates and electrophysiological correlates are observed for these processes. For instance, many of the dual accounts assume that familiarity operates faster than recollection (Yonelinas et al., 2002). Supporting this, EEG studies have found that familiarity-based ERP correlates (e.g., FN400) are observed earlier than recollection-based ERP correlates (e.g., LPC) (Gruber et al., 2008; Hintzman, Caulton & Levitin, 1998; Hintzman & Curran, 1994; Li et al., 2017). Likewise, familiarity depends on brain regions activated earlier in the processing stream than those dominating recollection (Yonelinas, 2002). In addition, the duality of recognition memory performances is apparent in brain lesion studies. For example, amnesic patients who display substantial hippocampal atrophy

demonstrated superior memory performance in item recognition tests than associative recognition tests (Giovanello, Verfaellie & Keane, 2003). Given that the former and latter tests are assumed to reflect familiarity and recollection respectively (Giovanello, Verfaellie & Keane, 2003), amnesiacs might rely on familiarity-based processing when making recognition memory judgments, which might be operated outside of the hippocampal region. Therefore, these findings support the notion that recognition memory might depend on two different processes rather than a single continuous process and that these processes might be governed by distinct neuro-anatomical substrates.

Although there is empirical evidence regarding familiarity and recollection, the definition of these processes differs across dual-process models. In this sense, while some suggest that recollection and familiarity refer to retrieval processes or memory assessment systems, others argue that they are types of mnemonic information or subjective states. Another group, however, advocates that these two processes should be treated as memory storage locations or systems. Hence, the next section highlights the differential definitions and characterizations of recollection and familiarity across dual-process models.

1.2.1. Atkinson Model

According to Atkinson and colleagues (Atkinson & Juola, 1973, 1974; Atkinson, Hertmann, & Wescourt, 1974; Juola, Fischler, Wood, & Atkinson, 1971), recognition memory depends on a conditional search model. In this

model, familiarity dominates fast responses, but if familiarity yields equivocal responses, subjects adopt an extended memory search (Atkinson & Juola, 1973). Here, activation of nodes in lexical stores, where each word or object is represented by a particular node, is assumed to underlie familiarity (Atkinson & Juola, 1974). In this sense, access to a node retrieves a particular value for familiarity, which occurs relatively fast and is prone to give higher error rates (Atkinson & Juola, 1974). If the familiarity value does not provide a satisfactory confidence level about a given information, subjects engage in an extended search that guarantees the correct decision, which is reflected in greater response latency (Atkinson & Juola, 1974). Hence, nodes attributed to studied items would be more active than unstudied items, which is the basis for recognition judgments for a particular item (Atkinson & Juola, 1973).

This model overlaps with the previous models of signal-detection theory in the sense that subjects consider items ‘old’ only if items exceed an upper threshold (Juola, Fischler, Wood, & Atkinson, 1971). In addition, this model points to another lower threshold to determine whether an item is ‘new’ (Juola, Fischler, Wood, & Atkinson, 1971). For the items where the activation lies between these upper and lower thresholds, subjects consult an additional event-knowledge store containing encoded items to make recognition judgments (Juola, Fischler, Wood, & Atkinson, 1971), which reflects recollection.

1.2.2. Mandler Model

According to Mandler and colleagues (Mandler, 1980; Graf & Mandler, 1984; Mandler & Boeck, 1974; Mandler, Pearlstone, & Koopmans, 1969; Rabinowitz, Mandler, & Patterson, 1977), the recognition of a prior occurrence of an item depends on two processes: 1) intra-event state of integration (i.e., assessments of familiarity) and 2) elaboration (i.e., a slower memory search or recollection). In this model, a study episode for a particular item is followed by an elevated activation (or familiarity), of which the perceptual facet of an item is integrated into the memory (Mandler, 1980). Therefore, this integration (familiarity) is a key component of both recognition memory and implicit memory tasks (Graf & Mandler, 1984). Recollection, on the other hand, is described by the elaboration of contextual inter-item information, and hence, underlies both recognition memory and recall performances (Rabinowitz, Mandler, & Patterson, 1977).

The characterization of recollection and familiarity differ between the original model and the latter models of Mandler. Earlier, Mandler's model agreed with Atkinson's model in the sense that both models pointed to a conditional search process, meaning that recollection operated only if familiarity led to an ambivalent response (Mandler, Pearlstone, & Koopmans, 1969). Later, Mandler (1980) suggested that these two processes are subsidiary even though they are independent, with familiarity being a faster process than recollection.

1.2.3. Jacoby Model

Jacoby and colleagues (Jacoby 1991; Jacoby & Dallas, 1981; Jacoby & Kelley, 1992; Jacoby & Witherspoon, 1982; Whittlesea, Jacoby, & Girard, 1990) suggested that recognition memory judgments are based on either the subjective assessments of relative processing fluency (i.e., familiarity) that is susceptible to recognition errors, or a more reliable form of memory involving retrieval of contextual information about the study episode (i.e., recollection). In this sense, one major difference between recollection and familiarity is that while the former is assumed to be a consciously-controlled process, the latter is relatively more automatic (Jacoby & Kelley, 1992; Whittlesea, Jacoby, & Girard, 1990). Hence, familiarity and recollection are distinct processes operating jointly although familiarity is a faster process than recollection (Jacoby & Kelley, 1992; Whittlesea, Jacoby, & Girard, 1990).

The fundamental difference between the Jacoby model and previous models is that earlier models treated familiarity as an inherent characteristic of an item. This model, however, argues that familiarity is not necessarily a characteristic of an item; rather, it arises when faster processing is attributed to prior encounters with the item (Jacoby & Dallas, 1981). Therefore, if one item is processed relatively easier than another, subjects attribute this relative ease of processing to their prior encounter and judge that item as more familiar. In this sense, it has been demonstrated that processing fluency eases the perceptual identification of items in implicit memory tests, and thus familiarity might

contribute to perceptual implicit memory (Jacoby & Dallas, 1981). However, some studies have shown that familiarity might also contribute to *conceptual fluency*, which is the ease of processing of semantic aspects of an item (Jacoby, 1991). Thus, this model contradicts the Mandler model on the argument that familiarity is entirely associated with perceptual facets of an item, and further suggests that it should not be treated as equivalent to perceptual implicit memory (Jacoby, 1991; Jacoby & Kelley, 1992).

1.2.4. Tulving Model

Tulving and colleagues (Tulving, 1985; Tulving & Schacter, 1990; Tulving & Markowitsch, 1998; Nyberg, Cabeza, & Tulving, 1996) have pointed to the presence of three different memory systems: procedural, episodic and semantic memory. In this sense, the Tulving model is separate from classic two-factor theory models of recognition memory, but still included in this section due to its extension on recollection and familiarity. According to this model, procedural memory is involved in the recognition and incorporation of acts (Tulving, 1983, 1985), while semantic memory stores facts and information about general knowledge (Tulving, 1985). Episodic memory, on the other hand, includes personal experiences and their temporal relations (Tulving, 1972).

Initially, Tulving (1983) suggested that recognition memory consisted of procedural and prepositional memory, whereby the latter included episodic memory and semantic memory. In this regard, episodic memory and semantic

memory were considered as parallel and overlapping subsystems working in collaboration to store information (Tulving, 1983, 1985). Later, however, Tulving modified this notion and proposed that episodic memory involves a single distinct subsystem of semantic memory (Tulving, 1984). Therefore, information should be filtered by this unit of semantic memory to be encoded in episodic memory although episodic memory is assumed to operate faster in acquiring new information than semantic memory (Tulving, 1984). In contrast, information can be separately retrieved from both systems at retrieval, where these systems run independently but coextensively (Tulving & Markowitsch, 1998).

To address the differential contributions of familiarity and recollection on recognition memory, Tulving (1985) introduced the "Remember and Know" procedure. In this procedure, subjects were asked to indicate Remember (R) judgments for the study items they could consciously recollect and Know (K) judgments when they have a sense of familiarity in the absence of conscious recollective experience. Results obtained from this procedure showed that episodic memory and semantic memory involved conscious experience of “remembering” (i.e., recollection) and conscious experience of “knowing” (i.e., familiarity in the absence of recollection) even though the term “conscious” represented autonoetic (i.e., one’s conscious awareness about concepts and facts in connection to their own experiences) and noetic (i.e., one's conscious awareness about concepts and facts in the absence of connections to their own

experiences) forms for episodic memory and semantic memory, respectively (Tulving, 1985).

1.2.5. Yonelinas Model

According to Yonelinas and colleagues (Yonelinas, 2001a, 2001b; Yonelinas, 2002; Yonelinas & Jacoby, 1994, 1996), recollection and familiarity are separate processes in terms of 1) the type of retrieved information, and 2) their distinctive contribution to recognition confidence. According to this model, recollection includes a retrieval threshold, where "qualitative" information about a prior event is retrieved, and therefore, reflects a threshold model (Yonelinas, 2001a). On the contrary, familiarity is assumed to be related to "quantitative" memory strength akin to that described in the signal detection theory (Yonelinas, 2001b). In this sense, several pieces of information might be recovered about an event, but the retrieval of qualitative information would be challenging as sometimes items fail to exceed the recollective threshold (Yonelinas, 2002). In such cases, one can rely on familiarity to make recognition judgments (Yonelinas, 2002).

In terms of recognition confidence, higher confidence is obtained when recollection is the primary source of judgment, which extends to several recognition confidence responses (Yoneinas, 2001a). Also, at the time of retrieval, recollection and familiarity are assumed to be independent but parallel processes, where familiarity operates faster than recollection (Yonelinas & Jacoby, 1994, 1996).

1.2.6. Neuro-Anatomical Models

Even though the findings from past neuro-psychological research remain inconsistent and controversial about neuro-anatomical underpinnings of recollection and familiarity, there is evidence that recollective experiences (such as learned associations) are hippocampal in nature (Ozubko et al., 2017), while perirhinal cortex subserves familiarity (Brown & Aggleton, 2001; Yonelinas et al., 2002; Ranganath, 2010). In this regard, one line of evidence about the disproportionate involvement of the hippocampus and perirhinal cortex in recollection and familiarity is derived from lesion studies. For example, in the case of hippocampal damage, recollective processes are hampered, whereas familiarity-based recognition is preserved (Ranganath, 2010). Respectively, amnesic patients with impaired hippocampal functioning rely on familiarity to make recognition judgments, suggesting selective deficits in recollection (Yonelinas, 2001). Supporting this, in one study, Bowles et al. (2010) found that hippocampal damage in temporal lobe epilepsy patients resulted in spared recollection-based responses, while familiarity-based responses remained intact. Therefore, these findings support the argument that the hippocampus and perirhinal cortex dominate recollection- and familiarity-based recognition, respectively.

Although many agree about the distinct role of the hippocampus on recollection, other studies highlight the critical role of hippocampal activity on familiarity. In this sense, there is growing evidence suggesting that surrounding

hippocampal structures play a key role in familiarity (Yonelinas, 2001). Respectively, Yonelinas et al. (2002) found that patients with mild hypoxia suffered from severe hippocampal damage while parahippocampal regions were preserved. Among these patients, substantial interference in recollection-based responses was observed, whereas no detrimental effects were found for familiarity-based responses. Yet more extensive temporal lobe damage hindered familiarity-based responses, suggesting that surrounding hippocampal regions support recognition familiarity (Yonelinas, 2002). Thus, even though patients with selective hippocampal damage display substantial recollection deficits, patients with extended hippocampal lesions exhibit impairments in both recollection and familiarity judgments.

Most studies have focused on the role of the medial temporal lobe in recognition memory; however, frontal activations are also demonstrated in recognition judgments. Regarding this, some studies suggested that the frontal lobe is involved in familiarity-based recognition, but not in recollection-based responses (Yonelinas, 2002). Supporting this, in one study, MacPherson et al. (2008) found deteriorated familiarity-based judgments in response to frontal lesions, while recollection-based judgements were unaffected, which is supported by other focal frontal lesion studies (Duarte, Ranganath, & Knight, 2005). However, not all studies are in line with this notion. For instance, contrary to the above findings, there is also evidence that prefrontal regions are involved in both recollection and familiarity, but activation is

observed in distinct prefrontal regions for each process. For instance, Scalici, Caltagirone & Carlesimo (2017) suggested that recollective activations were located more on the rostral subregion on the medial prefrontal surface, while more activation was demonstrated in dorsomedial prefrontal cortex (dmPFC) for familiarity, suggesting that frontal regions might be critical for both processes.

Altogether, these findings suggest that both medial temporal lobe (MTL) and regions outside of MTL support recognition judgments, but these findings are far from concluding the concrete neuro-anatomy of recognition memory processes.

1.3. Characteristics of Recollection and Familiarity

1.3.1. Controlled and Automatic Distinction

Over the years, dual-process models have portrayed several characteristic differences in recollection and familiarity. One difference repeatedly addressed by these models is that recollection is assumed to be a controlled process, while familiarity is relatively automatic (Oberauer, 2018). In this sense, substantial evidence is obtained from the division of attention studies regarding this phenomenon (Jacoby, Woloshyn & Kelley, 1989; Parkin & Russo, 1990). For instance, in a series of experiments, Gardiner and Parkin (1990) explored the effects of divided attention on recollection and familiarity. In these experiments, half of the subjects were asked to learn a list of words while the

other half were simultaneously given a tone-monitoring test, where they indicated whether the presented tones were high, medium, or low pitch. At test, remember and know judgments (see Tulving, 1985) were taken from subjects. Results showed that remember judgments were significantly impaired in the divided attention condition, compared to the undivided attention condition, while know responses remained unchanged across conditions (Gardiner & Parkin, 1990). Hence, this suggests that conscious attention might be critical for recollective experiences, whereas familiarity might be relatively less sensitive to changes in attentional resources.

In contrast to accounts arguing that familiarity is thoroughly an automatic process, there is evidence that it might be partially automatic at retrieval. For example, familiarity-based processes are present earlier than recollection-based processes under speeded test conditions (Yonelinas, 2002). Yet extremely speeded test conditions hinder familiarity-based recognition (Yonelinas, 2002). Likewise, similar results are obtained when subjects are deliberately asked to leave study items unattended (Yonelinas, 2002). Consequently, if familiarity were an absolute automatic process, it would remain intact even if conscious attention was limited.

Moreover, the argument of familiarity being an automatic process is particularly weak at encoding (Yonelinas, 2002). Divided attention studies have shown that even though the division of attention at encoding is more deleterious for recollective experiences than familiarity, familiarity-based

recognition is still hindered (Yonelinas, 2002; Curran 2004). This means that although recollection is more attention-demanding than familiarity, additional attention might positively impact familiarity-based processing. Yet if familiarity operated thoroughly automatically, familiarity-based judgments would be preserved in response to alterations in attention. Taken together, these findings point out that familiarity might be relatively more automatic than recollection, but it should not be taken as an entirely automatic process.

1.3.2. Intermediate-Term and Long-Term Distinction

Besides the automatic and controlled nature of recollection and familiarity, the retention periods of these two processes have also been extensively discussed in literature. In this regard, several dual-process models argue that familiarity declines faster than recollection in short retention rates (Yonelinas, 2002; Mecklinger, 2006). Previously, Eichenbaum et al. (1994) pointed to the presence of an intermediate-term memory relying on parahippocampal regions, which is more inclined to forgetting in short retention intervals than hippocampal-dependent memory. Moreover, human lesion studies have shown that hippocampal and parahippocampal damage selectively interferes with associative and item-based memory, whereby these systems are associated with recollection and familiarity respectively (Giovanello et al., 2003). Therefore, hippocampal regions might be responsible for recollection, while parahippocampal areas might dominate familiarity (Martin et al., 2013; Wais, Squire & Wixted, 2009), and this neuro-anatomical distinction might underlie

the diverse retention rates of familiarity and recollection. An earlier study by Yonelinas and Levy (2002) would support the preceding notion, where the authors examined the effects of retention rates on familiarity and recollection through single-item recognition and word-pair association tasks. In the word-pair association task, subjects were presented with words either in red or green in lowercase letters and instructed to make associations between the given word and its respective colour, while in the single-item recognition task words were only presented in uppercase letters. Subjects then received the recognition task, whereby they were asked about the match of colour-word pair between encoding and test. Subjects were instructed to give "yes" responses if they remembered that the prompted colour at test matched the colour of the studied item (i.e., recollection), and if they were able to identify the word from the study phase but could not remember the respective colour (i.e., familiarity). To explore the effects of retention, subjects were tested on different study-test lags, and the results showed that familiarity was more susceptible to decline over short retention intervals than recollection.

In contrast to selective sensitivity of familiarity to short retention intervals, longer retention intervals affect both recollection and familiarity (Yonelinas, 2002). According to Eichenbaum and colleagues, as the interval between study and test phases increases, the slope of two forgetting functions should converge, meaning that there should not be significant differences in forgetting rates for both processes in longer retention intervals (Eichenbaum et al., 1994).

In this sense, Hockley and Consoli (1999) evaluated the long-term retention rates of familiarity and recollection based on item and association memory tests. They reported that both processes tend to decline across delays extending up to 7 days. Also, source and item memory, of which are often measures of recollection and familiarity, were demonstrated to decrease comparably over a period of 7 days in another study (Bornstein & LeCompte, 1995). Taken together, these findings suggest that familiarity might be subject to faster forgetting in short retention periods than recollection, but this trend disappears with extended durations.

1.3.3. Conceptual and Perceptual Distinction

Another ongoing debate about recollection and familiarity is whether recollection and familiarity reflect the conceptual or perceptual processing of items. In this sense, many studies have supported the argument that recollection is selectively associated with conceptual processing; and therefore, sensitive to conceptual manipulations (Yonelinas, 2002). In this regard, in a series of experiments, Gardiner (1988) elaborated on the effects of conceptual manipulations on recollection-based and familiarity-based judgments. In one of these experiments, Gardiner investigated the differential contributions of the *levels-of-processing effect* (i.e., enhanced memory performance of an item with deeper processing, Craik & Lockhart, 1972) on recollection and familiarity with generation and rhyming tasks at encoding. In the study, subjects either generated a semantic associate for each word or a rhyming word to the words

presented during the study, and engaged in a Remember/Know task at test. The results showed that generated words in the study yielded higher remember responses, while know responses were unaffected. These results were further replicated by Rajaram et al. (1993) in another study. Thus, these findings support the notion that conceptual processing selectively facilitates recollective experiences.

In addition to evidence suggesting a pure relationship between recollection and conceptual processing, other studies have demonstrated a similar link between familiarity and perceptual processing (Yonelinas, 2002). In this sense, another study by Gregg and Gardiner (1994) explored the effects of perceptual processing on recollection and familiarity in a series of experiments. In that study, the subjects were presented with words either in visual or auditory modes at study, followed by remember and know judgments at test. In the first experiment, authors found that the visual presentation of words resulted in higher know judgments while leaving remember judgments unchanged. In the second experiment, subjects were instructed to count the blurred letters in presented words to enhance the perceptual processing of items. In fact, none of the words contained blurred letters, but this manipulation resulted in a more apparent increase in know judgments, whereas no such effect was demonstrated in remember judgments. Supporting this, in another experiment, Rajaram (1993) showed that masked exposure to a word before its actual presentation resulted in more know judgments for studied words, whereas

remember judgments were insensitive. Hence, these findings highlight the selective effects of perceptual manipulations on familiarity-based recognition.

Even though there is cumulative evidence regarding the selective effects of conceptual and perceptual processing on recollection and familiarity, some findings are troublesome for this distinction. For example, in a series of experiments, Rajaram (1996) demonstrated that perceptual manipulations may also influence recollection-based responses. In the first experiment of that study, subjects were presented with pictures and words at encoding. At test, both studied and unstudied material were shown in pictorial format, and a *picture superiority effect* (i.e., enhanced memory for pictorial than verbal items, Curran & Doyle, 2011) was selectively found for recollection-based responses, meaning that perceptual overlap in study and test material resulted in an increase in recollection memory. Similarly, in the subsequent experiments, Rajaram (1996) manipulated perceptual fluency by altering the size (Experiment 2) and left-right orientation (Experiment 3) of line drawings between study and test phases and found that such alterations particularly hindered recollection-based responses. Likewise, in another experiment, Whittlesea (1993) investigated the modulatory effects of conceptual processing on recognition familiarity. In that experiment, target words were embedded at the end of conceptually related or unrelated sentence contexts. Results demonstrated that subjects were more likely to report a word as previously studied when the word was presented in conceptually predictive sentences,

suggesting that conceptual manipulations might also influence familiarity-based processing. These findings indicate that perceptual and conceptual manipulations might impact both recollection and familiarity depending on the manipulation type, and reports of selective sensitivity of recollection and familiarity to conceptual and perceptual processing need further addressing.

1.4. Perceptual-Fluency Hypothesis, Metamemory Judgments, and Recognition Performance

Despite the controversial findings about the sensitivity of recollection, and familiarity to conceptual and perceptual processing, familiarity was initially described in terms of the ease of perceptual processing of an item, which is termed as *perceptual fluency* (Jacoby, 1991). In this sense, it was assumed that increased match in perceptual aspects of study and test items yielded easier processing of items along with a greater sense of familiarity (Jacoby & Dallas, 1981). Later studies, however, argued the sole definition of perceptual fluency with familiarity and suggested that perceptual fluency might be related to other aspects of recognition memory.

One aspect of recognition memory, apart from familiarity, influenced by perceptual fluency are *metamemory judgments*, which are a broad range of terms including heuristics, beliefs and experiential processes that enable us to modulate our memory (Koriat & Helstrup, 2007). One common measure of metamemory judgments is *judgments of learning* (JOLs), which is the

confidence about the memorability of an item on a subsequent memory test (Rhodes, 2016). Although sometimes JOLs overlap with the actual memory performance, some cues lead to mixed memory predictions, where in fact, perceptual fluency is one. To address the relationship between perceptual fluency and metamemory judgments, several theories have been postulated over the years. One theory, however, has gained considerable attention. Referred to as *perceptual fluency hypothesis,* this theory posits that fluent items are considered more memorable than disfluent items (Begg et al., 1989; Hirshman & Mulligan, 1991; Nairne, 1988). In this regard, the perceptual fluency effect on metamemory judgments has been replicated in many studies with multiple manipulations, such as with font sizes (Rhodes & Castel, 2008; McDonough & Gallo, 2012), auditory modalities (Rhodes & Castel, 2009), or degraded images (Besken, 2016).

While perceptual fluency most of the time results in higher metamemory judgments at encoding, the relation between perceptual fluency and actual memory performance remains inconclusive. One line of evidence suggests that actual memory performances of perceptually fluent and disfluent items are often alike. As an instance, a number of studies have used *font-size effect* to demonstrate the impact of perceptual fluency on metamemory judgments and recognition performances. In these studies, subjects reported that they were more likely to remember the words presented with large font sizes (e.g., 48 fonts), compared to small font sizes (e.g., 18 fonts) (Rhodes & Castel, 2008;

McDonough & Gallo, 2012). The results showed that although subjects reported higher JOLs to words with large font sizes, there was no significant difference between recall performances for large- and small-font-sized words (Rhodes & Castel, 2008; McDonough & Gallo, 2012). Also, similar findings have been obtained for blurred words (Yue, Castel & Bjork, 2013) and words presented backwards (Besken & Mulligan, 2013) than their intact counterparts. Hence, these findings support the argument that perceptual fluency leads to higher metamemory judgments for verbal material, whereas the actual memory performance remains unchanged.

While people consistently expect a higher memorability for fluent items than disfluent items, in some cases, actual memory performance is improved by disfluency. This elevated performance of recognition in explicit memory tasks is referred to as *perceptual-interference effect* (Mulligan, 1996) and was first demonstrated by Nairne (1988) in a study, where subjects were presented with two lists of words, in which one was followed by an immediate secondary presentation of the same words with a masked pattern to induce disfluency. Their results showed that words in perceptual interference condition were recalled and recognized better than clear words, and these results were replicated in multiple studies (see Hirshman & Mulligan, 1991; Mulligan, 1996). For instance, Diemand-Yauman et al. (2010) asked subjects to learn about three types of aliens during encoding. Features of these aliens were displayed in texts with disfluent typeface (e.g., Comic Sans MS) or fluent

typeface (e.g., Arial). They found that information displayed in disfluent texts was remembered better than the ones with fluent typefaces. Likewise, in another study, Sungkhasettee, Friedman, and Castel (2011) presented inverted and upright words to subjects at encoding. Although JOL ratings were insensitive to perceptual fluency, their actual memory performance was higher for inverted than upright words on the following memory test. These suggest that disfluency might benefit actual memory performance despite the common belief that it adversely affects the memorability of items. Altogether, these findings indicate that, in general, perceptual fluency positively impacts metamemory judgments for fluent items, whereas the association between the perceptual fluency and actual recognition performance is less clear.

1.5. Perceptual-Interference Effect and Cognitive Effort

As stated earlier, familiarity and recollection are assumed to be sensitive to perceptual and conceptual manipulations, respectively. Therefore, familiarity- and recollection-based recognition memory is expected to be selectively influenced by perceptual and conceptual fluency manipulations. One possible reason underlying this duality might be that perceptual aspects of an item are assumed to be related to less effortful lower-level processing than conceptual aspects of the item, which often demands a higher-level processing due to its semantic nature (Yue et al., 2013). Yet the perceptual-interference effect might be troublesome for this distinction. Supporting this Bjork (1994) suggests that perceptual disfluency might be a “desirable difficulty” that improves learning

by effortful processing at encoding, which results in long-term retention. In this sense, disfluency might be a desirable aspect as it impedes the perceptual processing of an item and leads to the initiation of an additional higher-level processing to promote the connections between visual, acoustic, and semantic information in the perceptual system (Yue et al., 2013). Consequently, disfluent items might be more memorable than fluent items due to the stronger associations between these information types in the perceptual system. Based on these assumptions, perceptual disfluency might inquire into deeper and more elaborate processing, which is expected to be a recollection-based characteristic rather than a familiarity-based characteristic. Therefore, the controversial findings in the literature about the effects of perceptual fluency on recollection might arise from desirable aspects of perceptual disfluency at encoding.

Moreover, cognitive effort favours the perceptual-interference effect. The cognitive effort has been extensively studied with *depth-of-processing* manipulations, which demonstrated a greater recall of an item with deeper processing (Tyler et al., 1979). For instance, in one study, subjects were presented with complex and simple anagrams at encoding and a sentence completion task at test. Subjects were instructed to identify words appearing as simple and complex anagrams and complete a sentence with one of the two presented options that fit best to the given sentence. In this sense, the target word was evident in low cognitive effort conditions, but required further

processing in high cognitive effort conditions. Later, subjects were surprised with a free-recall test. The results showed that words in high cognitive effort conditions were remembered better than low cognitive effort conditions. Similarly, in a series of experiments, Jacoby (1991) presented subjects with normal words or anagrams and found that even though words presented in normal form facilitated the perceptual identification, recognition performance was higher for anagrams than clear words (also see Allen & Jacoby, 1990; Jacoby & Hollingshead, 1990). Hence, words in clear format might have been easier to identify, but greater effort to comprehend the letters in anagrams might have led to deeper processing, which resulted in higher recognition performances for anagrams than clear words. Taken together, these findings show that disfluency might improve actual memory performance based on its demand on cognitive effort, and the impact of this deeper processing on recollection- and familiarity-based responses needs further elaboration.

1.6. Aims of the Current Study

It is important to note that, although the relationship between perceptual fluency, metamemory judgments and memory performances is well studied, there is much unknown to discover. This is because 1) the findings about perceptual fluency and actual recognition performance are controversial, and 2) past research heavily relied on verbal material. Therefore, evidence is scarce regarding the effects of fluent and disfluent pictorial material on metamemory judgments and subsequent memory performance. In this sense, based on

previous findings about metamemory judgments on verbal material (Mueller et al., 2014; Yang, Huang, Shanks, 2018), we hypothesized that fluent pictures might be given higher memorability ratings than disfluent ones. The relationship between perceptual fluency and actual recognition performance, however, might be more complicated. On one hand, fluent images might result in a subjective ease of processing at encoding that lead to a superior memory performance for fluent images than disfluent images at recognition tests. In contrast, disfluent images might drive a deeper processing than fluent images at encoding and might be recognized better at test. Alternatively, if both forms of pictures result in a comparable ease of processing at study, there may be no significant differences between the memory performances for disfluent and fluent images. Therefore, in this study, we will further examine 1) the association between perceptual fluency and metamemory judgments, and 2) whether disfluent and fluent images lead to distinct recognition performances.

CHAPTER II

EXPERIMENT I

2.1. Method

A plethora of studies have suggested that perceptual fluency impacts our metamemory judgments (Begg et al., 1989). In this sense, the perceptual-fluency hypothesis suggests that fluent items are considered more memorable than disfluent items at encoding, which has been demonstrated across multiple studies (Besken, 2016; Rhodes & Castel, 2008; McDonough & Gallo, 2012). In contrast to the consistent findings about the effect of perceptual fluency on metamemory judgments, the findings about the association between perceptual fluency effect and actual recognition performance are controversial. While some studies have reported a similar memory performance for both fluent and disfluent items, (Besken & Mulligan, 2013; Yue et al., 2013) others argue that disfluency improves actual memory performance (Diemand-Yauman et al., 2010; Nairne, 1988). Yet given that these studies were mostly on verbal material, results extending to pictorial material remained inconclusive.

The current experiment was conducted to examine two questions. The first one was whether fluent and disfluent pictures lead to distinct metamemory judgments during the encoding as suggested in the literature. In this

sense, based on previous findings, we hypothesized that perceptually fluent pictures might also be considered more memorable than disfluent pictures in our study.

The second question was whether perceptual fluency would impact actual recognition performances for fluent and disfluent pictures. Based on the earlier results, three outcomes were expected: 1) if disfluency were a desirable difficulty as suggested by Bjork (1994), actual recognition performance would be better for disfluent (blurred) pictures than fluent (clear) pictures, 2) if the processing of disfluent and fluent pictures were akin, actual recognition performance for both formats would not differ, and 3) if disfluent pictures demanded an extremely complicated higher-level processing, actual recognition performance would be worse for disfluent pictures than fluent pictures.

2.1.1. Subjects

Thirty students of Bilkent University between ages 18 and 30 were recruited in exchange for course credit. Subjects were native Turkish speakers and reported normal or corrected-to-normal vision prior to experiment. All experimental procedures were approved by Bilkent Ethics Committee.

2.1.2. Apparatus

Study and test material were presented on ASUS computers using E-Prime 2.0 software. Subjects were asked to use a keyboard connected to the computer to type their responses.

2.1.3. Design

A within-subjects design was used to ensure that all subjects were exposed to the same stimuli with a counterbalanced order. The independent variable was the item type at study (blurred or clear pictures) along with a pseudo-brand name that would be asked in a subsequent recognition test. Dependent variables were metamemory judgments measured with judgments of learning (JOLs), on a scale between 0 (no confidence that I will remember) and 100 (absolutely confident that I will remember), and actual recognition performance. The order of pictures was randomized across all study trials.
At test, pseudo-brand names were presented with four matching object options and subjects were asked to indicate the matching object with the respective number assigned to it. Each object was presented only once in one of the four options.

2.1.4. Materials

A collection of fifty-six pictures of common objects along with pseudo-brand names were presented at study. Among these pictures, two of them were used as a practice to ensure that subjects thoroughly understand the procedure. Eight pictures were used as buffers, four of which were primacy and four others were

recency items. Among the remaining 46 items, 23 were presented in blurred format (created on GIMP 2.10.32 with Gaussian Blur Radius 10), while the remaining 23 were clear. Blurred and clear pictures were counterbalanced across conditions and presented to an equal number of subjects. The pseudo-brand names consisted of six letters, ordered as one consonant and one vowel to ensure their pertinence to Turkish grammar.

2.1.5. Procedure

Subjects were tested individually in Bilkent University psychology laboratories. The experiment lasted approximately 45 minutes. Before the study, subjects were asked to sign an informed consent statement for their voluntary participation in the study. The experiment consisted of three phases: encoding phase, distraction phase, and recognition phase. The experimenter gave the instructions before the experiment and answered questions if any. The instructions were simultaneously presented on the computer screen.

The experiment started with an encoding phase. Subjects were informed that they would be randomly presented with blurred and clear images that would be asked in an upcoming memory task and asked to type the pseudo-brand name of the object and press “ENTER” within 8500 ms. To avoid any confusion, a pseudo-brand name designated a specific object (e.g., Ferate-Shoe pair was blocked across conditions). Following the presentation of an object-brand pair, subjects were prompted with JOL ratings and asked to assign a number between 0 and 100 to indicate their likelihood of remembering that

object/pseudo-brand pair in the following memory test. Subjects pressed "ENTER" to proceed to the next pair.

After the encoding phase, subjects were directed to the 3-minute distraction phase. During the distraction phase, subjects were presented with patterns consisting of black and white squares on the computer screen. After the first pattern, a grey mask was presented, followed by the presentation of another pattern. Subjects were asked to indicate whether two consecutive patterns were identical or not by pressing the "E/e" and "H/h" keys on the keyboard for "Evet/Yes" and "Hayır/No" responses. Decisions on "Yes" and "No" responses were self-paced.

Finally, in the recognition phase, subjects were presented with the pseudo-brand names along with four object options. The objects were displayed with numbers between 1 and 4 and subjects indicated the objects which they believed were presented along with the pseudo-brand name at encoding by typing the respective number of the object. The pseudo-brand names allocated to 46 pictures were displayed in the same order to all subjects at test, and each object was displayed only once in one of the four options. The test phase was also self-paced.

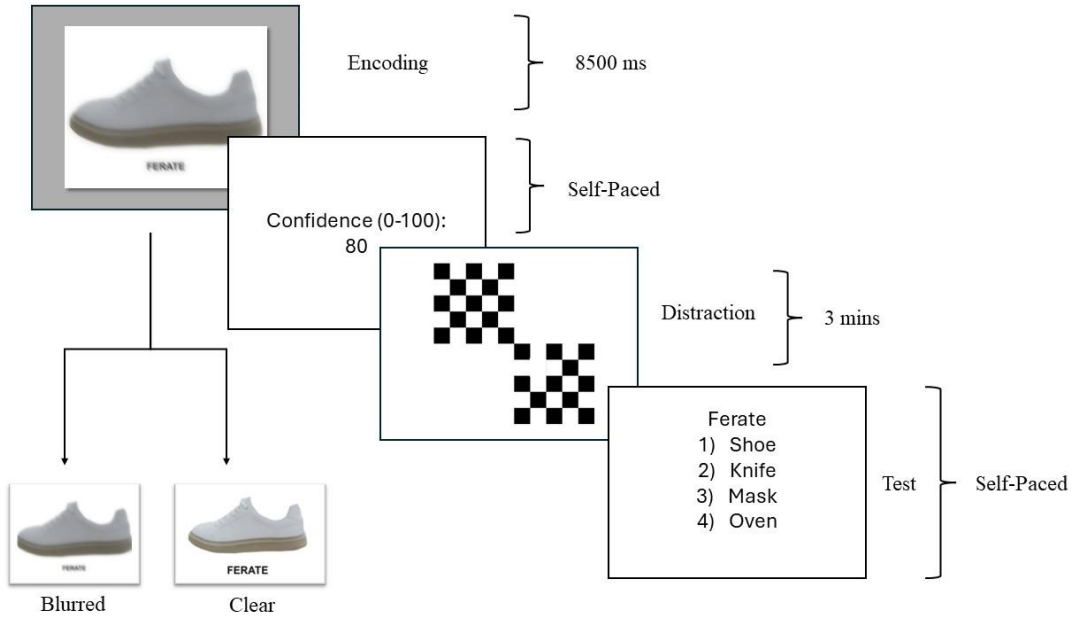

Figure 1. Schematic display of Experiment 1 depicting encoding, distraction, and test phases.

2.2. Results

All descriptive statistics for Experiment 1 are presented in Table 1. For all analyses alpha level was set at .05. To be included in this and the following experiments, subjects must have successfully identified and completed typing at least four of six letters of pseudo-brand names presented with objects, and identification rates were high for both blurred (99%) and clear (99%) images at encoding. All effect sizes are reported in terms of Cohen's *d*.

Table 1. Means and Standard Deviations (in Parentheses) for Fluent and Disluent Pictures in Experiment 1

	Identification Latency (ms)		Total Typing Time (ms)		Memory Predictions (out of 100)		Proportion of Correct Recall	
Exp. #	Clear	Blurred	Clear	Blurred	Clear	Blurred	Clear	Blurred
1	1568,36 (706,87)	1612,12 (763,80)	2356,79 (1276,81)	2354,49 (1262,80)	46,98 (27,74)	44,72 (29,05)	.57 (.17)	.56 (.17)

Average reaction times (RTs) for first-time key press and total typing time were calculated separately for each subject for clear and blurred images, excluding the trials where subjects misidentified or did not type the pseudo-brand name (0.7%). A paired-samples *t* test demonstrated that there was no significant difference between the first-time key press for blurred (*M* = 1612,12, *SD* = 763,80) and clear (*M* = 1568,36, *SD* = 706,87) images; *t*(29) = -1.40, *p* = .16, *d* = 0.06. Likewise, the encoding condition had no significant effect on total typing time for blurred (*M* = 2354,49, *SD* = 1262,81) and clear (*M* = 2356,79, *SD* = 1276,81) images; *t*(29) = .044, *p* = .97, *d* = 0.002. Moreover, similar results were obtained for subjects' metamemory judgments and although clear images (*M* = 46,98, *SD* = 27.74) were predicted as slightly more memorable than blurred images (*M* = 44,72, *SD* = 29.04), this effect was

not significant; $t(29) = 1.920$, $p = .06$, $d = 0.08$. Lastly, even though subjects rated clear images as marginally more memorable than blurred images at encoding, the actual recognition performances for blurred ($M = .56$, $SD = 0.17$) and clear ($M = .57$, $SD = 0.17$) images were not statistically different at test; $t(29) = .428$, $p = .67$, $d = 0.02$.

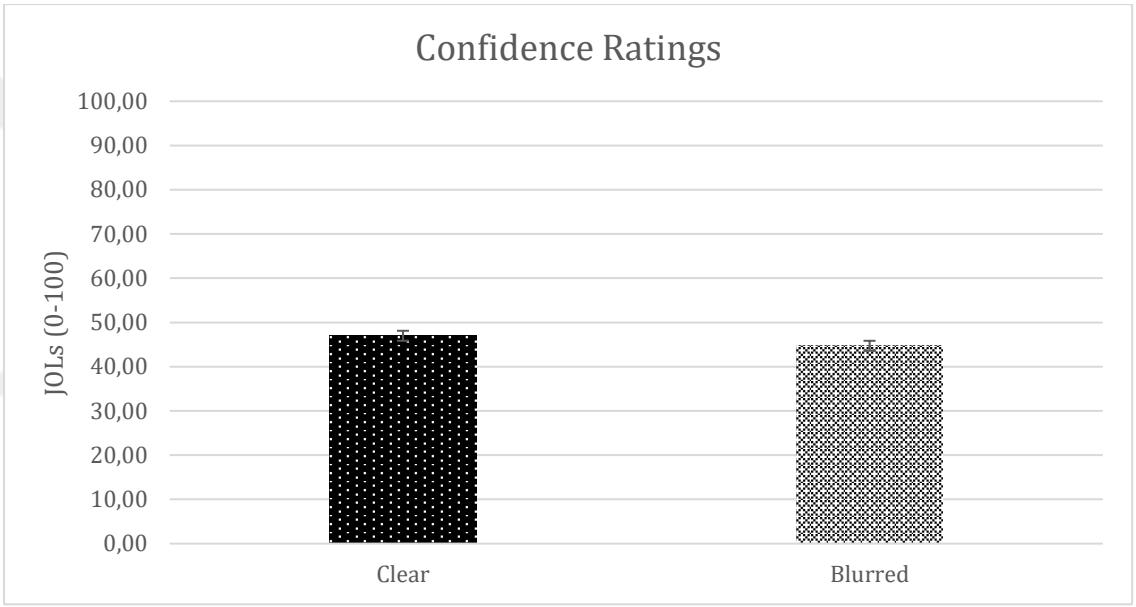

Figure 2. Mean confidence ratings for blurred and clear pictures. Error bars display the standard errors of the means.

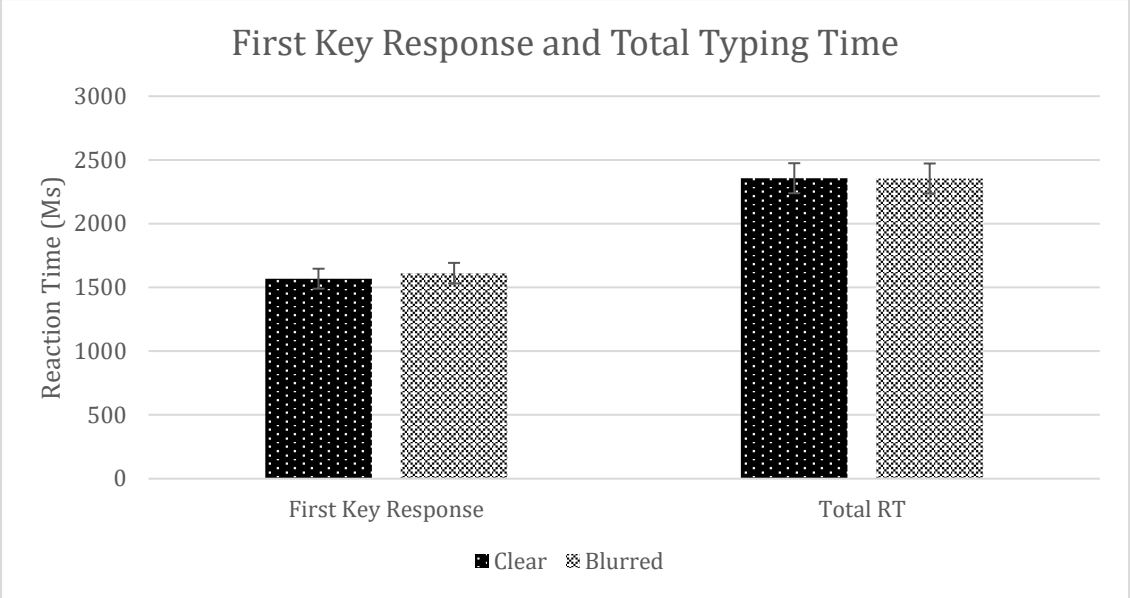

Figure 3. Mean first key press latency and total typing time for blurred and clear pictures. Error bars display the standard errors of the means.

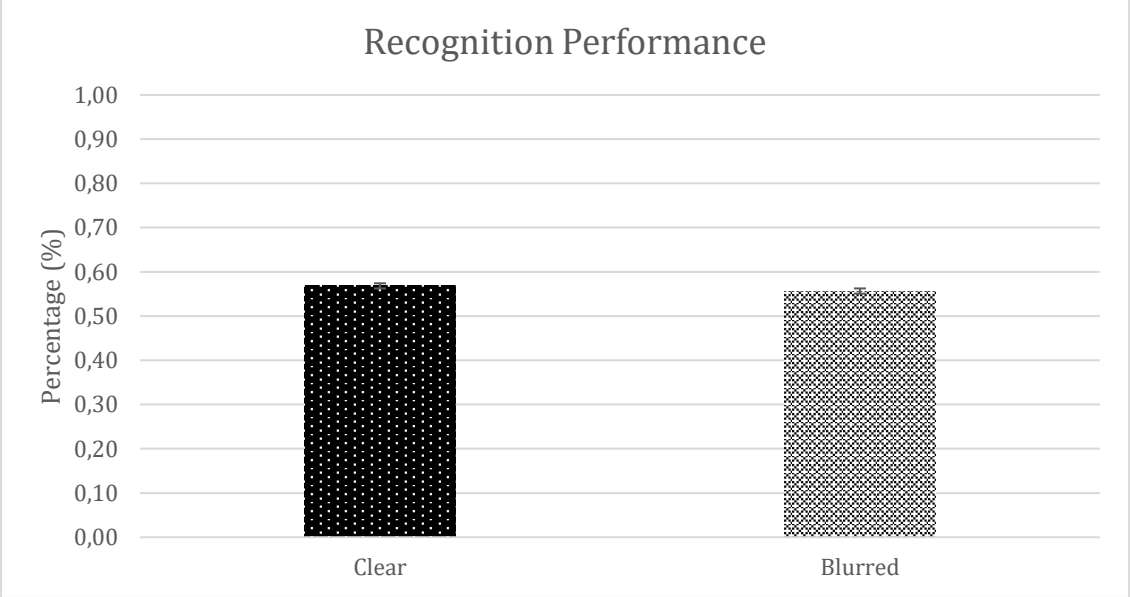

Figure 4. Mean recognition performance for blurred and clear pictures. Error bars display the standard errors of the means.

2.3. Discussion

In this experiment, we examined the effects of perceptual fluency on metamemory judgments through JOLs and actual recognition performance. The results of this experiment revealed that neither metamemory judgments nor actual recognition memory significantly differed in response to perceptual fluency although subjects gave marginally higher JOLs and marginally performed better when images were presented in clear format than blurred format. In this sense, even though insensitivity of actual recognition performance to perceptual fluency has been reported in several studies (Besken, 2016; Yue et al., 2013), our study contradicts with other studies demonstrating a positive relationship between perceptual fluency and greater memorability ratings at encoding (Rhodes & Castel, 2008; Rhodes & Castel, 2009). Yet given that the results demonstrated a slightly superior recognition performance for clear images than blurred images, whether blurriness alone was only partly successful at distorting visual acuity remained inconclusive. Hence, Experiment 2 addressed this issue, whereby inversion along with blurriness was used to manipulate perceptual fluency.

CHAPTER III

EXPERIMENT 2

The results of Experiment 1 showed that neither metamemory judgments nor actual recognition performance significantly differed between blurred and clear pictures. Although the effects of perceptual fluency on actual recognition performance are inconclusive, given that previous studies are often in agreement about higher JOL ratings for perceptually fluent items, our results might be partly explained by our main source of perceptual manipulation. In this sense, blurriness would be a minor manipulation of perceptual fluency (Lindenberger et al., 2001), meaning that blurriness as a sole source of manipulation would not suffice to complicate the perceptual processing of disfluent items, and respectively, induce a deeper or impaired processing. Therefore, besides blurriness, *the inversion effect* (i.e., harder recognition for inverted objects than upright objects) was also implemented on pictures in this experiment to induce more elaborate, or at least distinct, processing of items (Sungkhasettee, Friedman & Castel, 2011).

Also, our ultimate goal in this study was to explore the effects of perceptual manipulations on recollection and familiarity. However, some studies have suggested that metamemory judgments sometimes alter actual recognition

performance. This phenomenon is known as *the JOL reactivity effect*, in which the memory performance for JOL-rated items are different than nonrated items at a recognition test (Mitchum et al., 2016). The current study aimed to eliminate any confound derived from the reactivity effect of metamemory judgments; thus, in Experiment 2, subjects were not prompted with JOL ratings.

As mentioned above, the focus of this study was on the effects of perceptual fluency on actual recognition performance. Akin to Experiment 1, three possible outcomes were expected in this experiment: 1) if blurriness and inversion together were able to generate a desirable difficulty (and more elaborate processing), actual recognition performance would be better for disfluent (i.e., blurred and inverted) than fluent (i.e., clear) pictures, 2) if the processing of disfluent and fluent pictures were similar to each other, there would be no significant difference in recognition performance between formats, and 3) if disfluent pictures demanded an extremely complicated higher-level processing, actual recognition performance would be worse for disfluent pictures than fluent pictures.

3.1. Method

3.1.1. Subjects

Fourty eight students of Bilkent University between ages 18 and 30 were recruited in exchange for course credit. Subjects were native Turkish speakers and reported normal or corrected-to-normal vision prior to experiment.

3.1.2. Apparatus

Study and test material were presented on ASUS computers using E-Prime 2.0 software. Subjects were asked to use a keyboard connected to the computer to type their responses.

3.1.3. Design

A within-subjects design was used to ensure that all subjects were exposed to the same stimuli with a counterbalanced order. The independent variable was the item type at study (blurred and inverted or clear pictures). Dependent variable was recognition performance for both formats. At test, subjects were presented with studied (“old”) and non-studied (“new”) alternative matching items and asked to make simple recognition judgments about whether they were presented with the prompted item at encoding.

3.1.4. Materials

The stimuli for this experiment consisted of 172 pictures of single-word common objects, such as “computer”. At encoding, four (two disfluent and two fluent) objects were practised to ensure a thorough understanding of the

encoding procedure. Eight pictures served as a buffer, four of which were primacy and four were recency items. 80 pictures were shown at encoding. Among the 80 items, 40 were blurred and inverted (created on GIMP 2.10.32, with Gaussian Blur Radius 10), while 40 were clear. At test, an additional set of 80 items were presented to subjects. As of encoding, 40 alternative objects were presented in a blurred and inverted format, whereas the remaining 40 were clear. Blurred and inverted and clear pictures were counterbalanced across conditions and presented to an equal number of subjects.

3.1.5. Procedure

Subjects were tested individually in Bilkent University psychology laboratories. The experiment lasted for approximately 45 minutes. Before the study, subjects were asked to sign an informed consent statement for voluntary participation in the study. The experiment consisted of three phases: encoding phase, distraction phase and recognition phase. The experimenter gave the instructions prior to the experiment and answered questions if any. The instructions were simultaneously presented on the computer screen.

The experiment started with the encoding phase. Subjects were informed that they would be randomly presented with blurred and inverted (disfluent) or clear (fluent) images and asked to indicate the common name of the object with one word and press “ENTER” within 8500 ms to proceed to the next item. Subjects were instructed to keep the objects in mind for an upcoming memory

test. The presentation of disfluent and fluent forms of images was counterbalanced across conditions.

After the encoding phase, subjects were directed to the 3-minute distraction phase. During distraction, subjects were presented with patterns consisting of black and white squares on the computer screen. After the first pattern, a grey mask was presented, followed by the presentation of another pattern. Subjects were asked to indicate whether two consecutive patterns were identical or not by pressing the “E/e” and “H/h” keys on the keyboard for “Evet/Yes” and “Hayır/No” responses, respectively. Decisions on “Yes” and “No” responses were self-paced.

Finally, in the recognition phase, subjects were randomly prompted with the objects either they studied at encoding or their matching alternatives, and asked to press “E/e” for the objects they recognized from encoding phase, and “H/h” for the objects they could not recognize from encoding phase, whereby “E/e” and “H/h” reflect “Evet/Yes” and “Hayır/No” responses, respectively. Also, half of the test objects were matching alternatives of the pictures at encoding (such as two distinct computers); therefore, subjects were instructed to give “Yes” responses only if the prompted picture was completely identical to the study item at encoding, and that any object resembling the original item should receive a “No” response. In addition, subjects were instructed that if the item was presented as clear at encoding and blurred and inverted at test (or vice versa), that item would still receive a “Yes” response. The presentation of

studied and non-studied items were counterbalanced at test, and decisions on this phase were also self-paced.

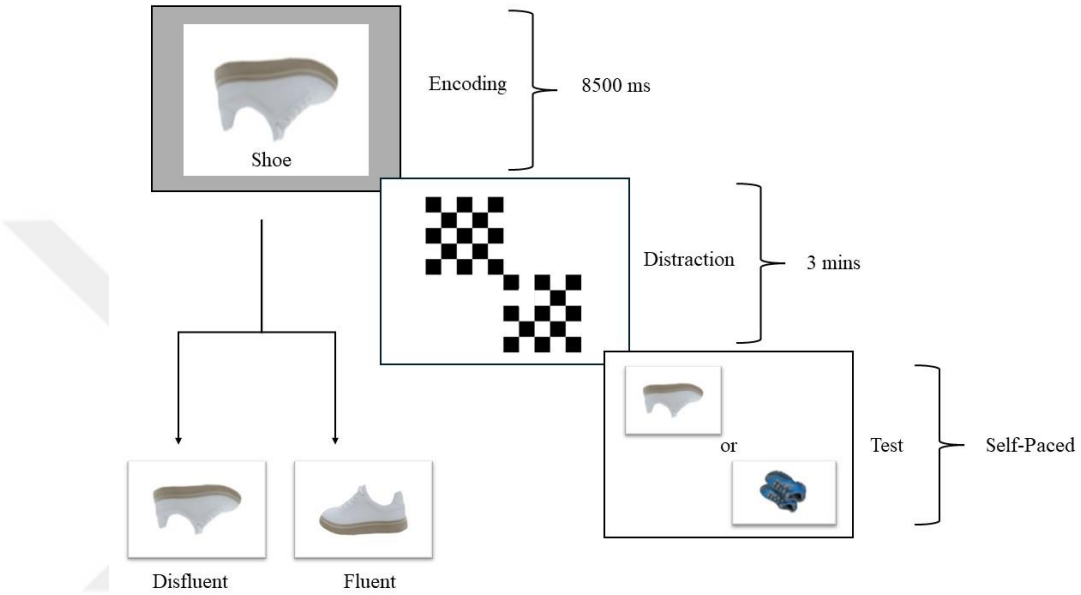

Figure 5. Schematic display of Experiment 2 depicting encoding, distraction and test phases.

3.2. Results

All descriptive statistics for Experiment 2 are presented in Table 2. For all analyses alpha level was set at .05. To be included in this and the following experiments, subjects must have successfully identified and completed typing object names, and identification rates were high for both blurred and inverted (95%) and clear (98%) images at encoding. All effect sizes are reported in terms of Cohen's *d*.

Table 2. Means and Standard Deviations (in Parentheses) for Fluent and Disfluent Pictures in Experiment 2

	Identification Latency (ms)		Total Typing Time (ms)		Proportion of False Alarm		Proportion of Corrected Hit		Proportion of Correct Recall	
Exp. #	Fluent	Disfluent	Fluent	Disfluent	Fluent	Disfluent	Fluent	Disfluent	Fluent	Disfluent
2	1436,30 (182,36)	1419,40 (179,90)	1612,98* (292,24)	1425,78* (347,91)	.10 (.08)	.11 (.08)	.35 (.09)	.33 (.10)	.44 (.08)	.44 (.08)

Note. * $p < 0.05$, using paired-samples *t* test.

Average reaction times (RTs) for first-time key press and total typing time were calculated separately for each subject for clear (fluent) and blurred and inverted (disfluent) images, excluding the trials where subjects misidentified or did not type the object name (3.2%). A paired-samples *t* test demonstrated that there was no significant difference between the first-time key press for disfluent (*M* = 1419,40, *SD* = 179,90) and fluent (*M* = 1436,30, *SD* = 182,36) images; $t(47) = -.757$, $p = .45$, $d = 0.09$. In contrast, there was a statictically significant difference between the total typing time for disfluent (*M* = 1425,78, *SD* = 347,91) and fluent (*M* = 1612,98, *SD* = 292,24) images; $t(47) = -6.342$, $p < .05$, $d = 0.58$.

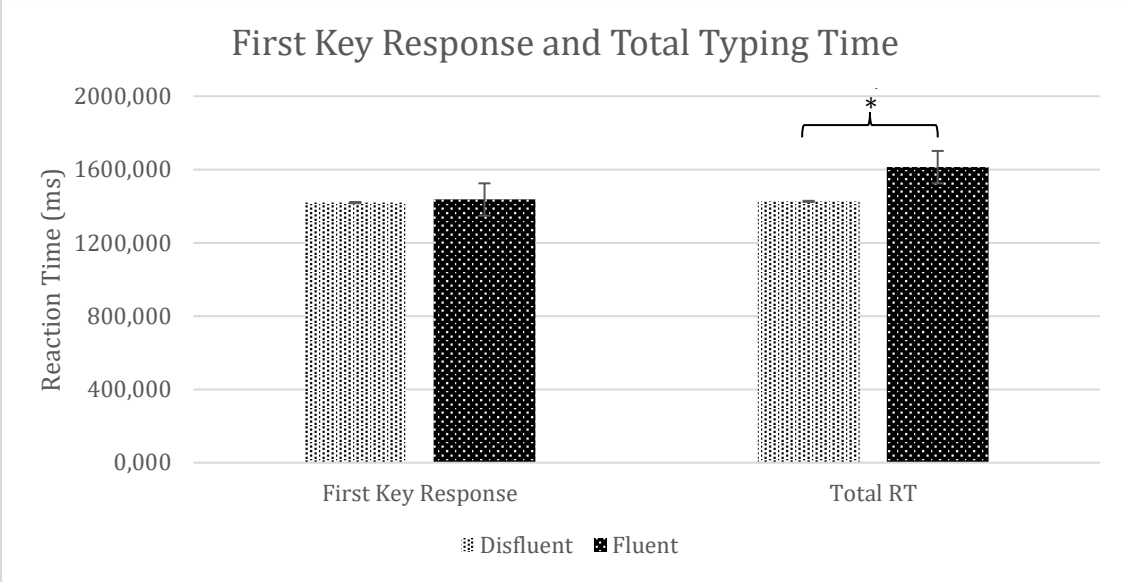

Figure 6. Mean first key press latency and total typing time for disfluent and fluent pictures. Error bars display the standard errors of the means.

A paired-samples *t* test showed that there was no statistically significant difference between the hit rates for disfluent (*M* = .44, *SD* = .08) and fluent (*M* = .44, *SD* = .08) images at test; *t*(47) = -.16, *p* = .88, *d* = 0.02. Also, false alarm rates were calculated for both forms of pictures based on the recognition responses given to studied pictures (presented in both encoding and test) and alternative non-studied pictures (presented only at test). A paired-samples *t* test demonstrated that false alarm rates were also comparable for both forms of pictures (disfluent, *M* = .11, *SD* = .09; fluent, *M* = .10, *SD* = .07), *t*(47) = .60, *p* = .55, *d* = 0.09. Besides hit and false alarm rates, corrected hit rates were calculated for both disfluent and fluent images by subtracting the false alarm rates from hit rates for both formats. Then, a paired-samples *t* test was

conducted to determine whether there was any statistical difference between corrected hit rates of disfluent and fluent images. The results showed that there was no statistically significant difference between the corrected hit rates of disfluent (M = .33, SD = .10) and fluent (M = .35, SD = .09) images; $t(47)$ = -.69, p = .49, d = 0.10.

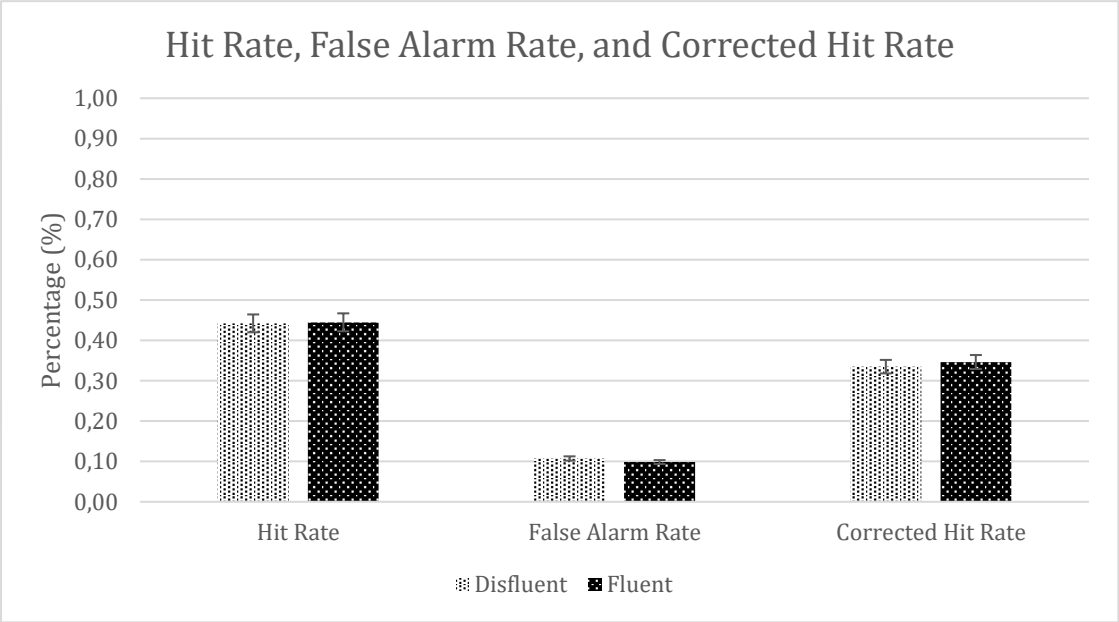

Figure 7. Proportion of hit rate, false alarm rate and corrected hit rate for disfluent and fluent pictures. Error bars display the standard errors of the means.

3.3. Discussion

In this experiment, our focus was on the effects of perceptual fluency on actual recognition performance. The results of this experiment revealed that recognition performance was similar for both disfluent and fluent images despite the multiple sources of manipulations (inversion and blurriness) to

further hinder visual acuity. Given that identification rates were high for both formats of pictures, it is possible that neither of the manipulations sufficed to properly induce perceptual disfluency. Yet similar results have been reported in multiple studies using different forms of perceptual manipulations (Rhodes & Castel, 2008; Rhodes & Castel, 2003). Therefore, another explanation for these results might be that actual recognition performances might be insensitive to perceptual fluency manipulations regardless of the manipulation types.

CHAPTER IV

GENERAL DISCUSSION

Recognition memory has been subject to an ongoing debate about whether it involves a single continuous process or two different processes. Single-process models propose that recognition memory comprises a single memory unit relying on the memory strength and stimulus recency, termed as familiarity (Pratte & Rouder, 2011). These models, however, were incomplete in terms of thorough explanation of episodic experiences of recognition during a study episode (Ozubko, Moscovitch, & Winocur, 2017). Consequently, dual-process models have arisen to address the episodic aspects of recognition memory.

According to dual accounts, recognition memory consists of two distinct subprocesses: 1) familiarity and 2) recollection, which refers to the conscious reliving of a specific study episode (Diana et al., 2006). In this sense, recollection and familiarity have been differentially characterized in dual-process models in terms of their automatic or controlled nature, endurance, and divergent response to perceptual and conceptual manipulations, which is the focus of this study. A number of studies have shown that while recollection is only responsive to conceptual manipulations, familiarity is selectively influenced by perceptual manipulations (Gardiner, 1988; Rajaram, 1993). Yet

not all studies are in line with this notion. For instance, Rajaram (1996) demonstrated that altered size and left-right orientation of line drawings, which were considered as perceptual in nature, across study and test hindered recollection-based responses, while familiarity-based responses remained intact. Likewise, in another study, Whittlesea (1993) found that presenting words in conceptually predictive sentences improved familiarity-based processing, suggesting that familiarity might be sensitive to conceptual manipulations, as well as perceptual manipulations. Therefore, implications of perceptual and conceptual manipulations on recollection and familiarity remain inconclusive.

In terms of the impact of perceptual aspects of recognition memory, several theories have been postulated over the years. One of these theories is the perceptual-fluency hypothesis. In general, perceptual fluency refers to the ease of processing of perceptual and formal features of an item (Alter & Oppenheimer, 2009; Oppenheimer, 2008), and perceptual-fluency hypothesis posits that items that are easier to process receive higher metamemory judgments (Susser, Mulligan & Besken, 2013), which are a range of heuristics, beliefs and experiential processes to avail memory (Koriat & Helstrup, 2007).

One common method to explore the influences of perceptual fluency on metamemory judgments is the judgments of learning (JOLs), which is a confidence rating about the memorability of an item on a subsequent recognition test (Rhodes & Tauber, 2011). Supporting the perceptual-fluency

hypothesis, studies have consistently found that perceptually fluent items are reported more memorable than perceptually disfluent items (Undorf, Zimdahl & Bernstein, 2017; Undorf & Zimdahl, 2019; Yang, Huang & Shanks, 2018). As an instance, in one study, Undorf et al. (2017) investigated the relationship between stimulus sizes and JOL ratings, in which they presented subjects with faces, words and common objects with varying sizes. They found a negative relationship between response latency and JOL ratings, meaning that as the time to identify an item decreased (i.e., perceptual fluency), the item was considered more memorable. Therefore, easily perceived items often receive higher metamemory judgments, compared to items demanding more elaborate processing.

Despite a demonstrated positive relationship between perceptual fluency and metamemory judgments, the association between perceptual fluency and actual recognition performance is less clear. In this regard, some studies have shown that even though perceptually fluent items received higher JOLs than disfluent items at encoding, actual recognition performances for perceptually fluent and disfluent items were similar (Kornell et al., 2011; Hu et al., 2016; Rhodes & Castel, 2008). As an instance, Rhodes and Castel (2008) investigated the font-size effect on metamemory judgments and actual memory performance. They found that actual recognition performances for both forms did not differ although subjects predicted a higher memorability for larger font sizes than smaller font sizes. This pattern was also observed in the auditory modality. For

instance, in one study, subjects were presented with words over headphones with high and low volumes (Rhodes & Castel, 2009). Even though words presented with high volume were given higher memorability ratings at encoding than with low volume, actual memory performance was insensitive to volume level. Altogether, these findings support the argument that metamemorial illusion driven by perceptual fluency might not extend to recognition performance.

Alternatively, some studies have suggested a positive impact of perceptual disfluency on actual recognition performance. In the original paradigm, Nairne (1988) presented subjects with clear words and words occluded by a mask at encoding. The results showed that words in interference conditions were recalled and recognized better than intact words. Such improvement in explicit memory tasks due to perceptual disfluency was then referred to as perceptual-interference effect, and this effect was maintained across multiple studies (Hirshman & Mulligan, 1991; Mulligan, 1996). Even though the precise mechanism of perceptual-interference effect is yet to be deciphered, one explanation for this phenomenon comes from Bjork (1994). According to Bjork (1994) perceptual disfluency imposes a desirable difficulty at encoding, which requires a deeper processing, and ultimately results in long-term retention. However, given that elaborate processing is attributed to recollection-based recognition rather than familiarity-based recognition, perceptual interference would be troublesome for the distinctive impacts of

conceptual and perceptual manipulations on recollection and familiarity. In other words, in contrast to many studies suggesting a pure association between familiarity and perceptual processing, perceptual manipulations might also impact recollective experiences at encoding and subsequent recognition performances.

4.1. Metamemory Judgments

One common aspect of the studies investigating the association between perceptual fluency and recognition memory was that these studies were dominated by verbal material. In this sense, how the above findings extended to pictorial material remained elusive. To address the implications of the above notions on pictorial material, some strategies have been used in previous research. Some of the strategies were inversion (Albonico et al., 2018), fragmentation of images (Besken, 2016), or presenting pictures from a canonical or non-canonical viewpoint (Besken et al., 2019). Yet blurriness and its impact on visual acuity have been overlooked. To the best of our knowledge, only one study implemented blurriness as the source of visual manipulation, but this study was also on verbal material. In this series of experiments, Yue et al. (2013) presented subjects with blurred and clear words, followed by immediate JOL ratings. Later, subjects were given recall and recognition tests. The results showed that even though actual memory performance remained comparable at recognition tests for both word formats, and worse for blurred words in recall tests, subjects consistently reported

higher JOLs for clear words than blurred words, demonstrating the impact of blurriness on visual acuity. Yet given that these results were obtained for verbal material, whether the results for pictures would be similar to words remained elusive. Therefore, in Experiment 1 of our study, blurriness was used as the source of perceptual manipulation, and to the best of our knowledge, this was the first study to explore the effects of blurriness on metamemory judgments and actual recognition performance for pictorial material.

Previous research about the association between perceptual fluency and metamemory judgments often found a positive relationship between perceptual fluency and JOL ratings for perceptually fluent items regardless of the source of perceptual manipulation. This perceptual fluency effect was also demonstrated in Yue et al's study (2013), where blurriness was the source of perceptual manipulation. Based on these findings, one would expect blurred images in Experiment 1 of our study to receive lower JOL ratings compared to clear images. However, contrary to our expectations, our results showed that there was no significant difference between the JOL ratings for blurred and clear images. One reason for these results might be that metamemory judgments are distinctively influenced by verbal and pictorial materials. In this regard, pictorial and verbal materials might be qualitatively different at encoding that uniquely influences metamemory judgments.

As indicated above, qualitative differences between pictorial and verbal material might perpetuate distinct cognitive processes at encoding, which

might serve as the basis for comparable JOLs in Experiment 1. In this sense, some researchers have advocated the *multiple semantic system model*, positing differential conceptual representations of pictorial and verbal stimulus. For example, Paivio's *dual coding theory* points to the "imagen" and "logogen" processing of pictorial and verbal material, respectively (Paivio, 1975). Therefore, while a verbal system might dominate the processing of verbal material, an imaginary system might underlie the processing of pictorial material (Paivio & Clark, 2006). Alternatively, a semantic code might underlie both pictures and words (Nelson, Reed, & Walling, 1976; Mintzer & Snodgrass, 1999), but pictures might be richer in sensory-perceptual codes and more direct to access to the semantic code compared to words (Nelson, Reed, & Walling, 1976; Mintzer & Snodgrass, 1999). In contrast, words might access phonemic and orthographic processes before initiating the semantic code (Nelson, Reed, & McEvoy, 1977; Dewhurst & Conway, 1994). Hence, the processing of words might depend on language-specific processes and fail to extend to conceptual processing, meaning that the representation of words entails fewer sensory-perceptual details and poor semantic processing reports.

In terms of the differential encoding of pictures and words in the perceptual system, Amit, Algom and Trope (2009) suggested that pictures might instigate perceptual processing akin to that of actual objects due to the perceptual overlap between pictures and physical referents, while words are distinctively represented than their physical referents. Consequently, representations of

pictures might be more specific and concrete than words due to the differences in perceptual analysis of pictorial and verbal material, which would ease the processing pictures. In contrast, *visual similarity hypothesis* suggests that such physical resemblance might be disadvantageous for processing of pictures of biological objects (Kahlaoui et al., 2007). According to this hypothesis, visual identification of biological objects demands longer processing than man-made objects (Kahlaoui et al., 2007). Thus, the processing of world object images might be more challenging than man-made objects. Taken together, these studies point to the inconclusive results about relatively more automatic or elaborate processing of visual material across studies, and given that our study included pictures of real-world objects, this might uphold different metamemory judgments for pictures in our study and words in past research.

Based on the above arguments, an alternative explanation to comparable results in our study might be the subjective ease of processing degraded pictorial material. So far, studies with words have consistently reported lower metamemory judgments for disfluent words than their intact counterparts. (Besken & Mulligan, 2013; 2014). In contrast, encoding of the visual world often demands the processing of objects interfered with or occluded by other objects, yet these objects are still identified (Besken, 2016). Therefore, interference might have a limited, if any, impact on the encoding of the visual world around us, which might also be the case for the processing of disfluent pictures. In other words, subjects might not feel as much objective perceptual

difficulty as recognizing disfluent pictures, compared to disfluent words and this might result in comparable memorability judgments for both clear and blurred images. Supporting this, in one study, subjects were presented with complete and incomplete pictures at study, followed by a surprise source memory task (Foley, Foley, Durso & Smith, 1997). The results showed that subjects mistakenly reported incomplete pictures in their complete form, which suggests that perceptual analysis of incomplete pictures at encoding might be parallel to the processing of complete pictures. Therefore, this supports the argument that the compensation of disfluent images might be distinct from that of disfluent words, and disfluent images might be processed parallel to fluent images. Consequently, it is possible that blurred and clear images in Experiment 1 in our study were given similar JOLs due to the parallel subjective ease of processing of both pictorial formats.

Moreover, even though mastery is obtained to identify occluded objects in real life, metamemory judgments do not always follow the ease of encoding in the presence of other cues. Regarding this, metamemory judgments might be influenced by other sources, such as a priori beliefs. This phenomenon is first described by Koriat (1997) as a *cue utilization framework*, which suggests that a priori beliefs influence subsequent metamemory judgments about items. In this sense, people might have an established belief about the similar memorability of disfluent and fluent images. As far as we know, only one study investigated the role of beliefs on JOL ratings for degraded and clear

images (Besken, 2016). The results of this study showed that there were no uniform a priori beliefs about the memorability of degraded and clear images, and in fact, these beliefs might be generated during experiment. In our experiment, subjects were not tested about their a priori beliefs on pictorial material, and therefore, whether they indicated similar memorability for clear and blurred images due to their a priori beliefs needs further addressing.

4.2. Actual Recognition Performance

Even though perceptually fluent items are often predicted as more memorable than disfluent items, findings on the actual memory performance for fluent and disfluent items is controversial. On one hand, some studies have found that actual memory performance is similar for both fluent and disfluent items (Rhodes & Castel, 2008; McDonough & Gallo, 2012). As an instance, studies have shown that although words presented in larger font sizes are expected to be more recognizable than small words, memory performance for these words are akin to each other (Mueller et al., 2014; Rhodes & Castel, 2008). Contrary to this, there are some studies demonstrating the perceptual-interference effect on actual memory performance, whereby the actual recognition performance is improved by disfluency in explicit memory tests (Hirshman & Mulligan, 1991; Nairne, 1988; Mulligan, 1996). Yet the foregoing studies depended on verbal material and whether these findings extended to pictorial material remained inconclusive. In this sense, we further elaborated on whether disfluent and fluent images distinctly affected the actual recognition performance. Overall,

our results of both Experiments 1 and 2 failed to demonstrate a significant difference in recognition performance for disfluent and fluent images.

As indicated above, several manipulations have been implemented to explore the relationship between perceptual fluency and actual recognition performance on pictorial material. However, blurriness has been poorly studied in the past. In fact, to the best of our knowledge, this is the first study to implement blurriness as a source of perceptual disfluency on pictorial materials. In this sense, the effects of blurriness on recognition memory were first investigated by Yue et al. (2013), but with verbal material. Their results showed a superior memory performance for clear words than blurred words in recall tests and comparable performance in recognition tests. Therefore, we aimed to further investigate the mnemonic effects of blurriness on recognition memory performance for pictorial material. In line with the previous study, our results also failed to demonstrate a significant difference between the actual memory performances for blurred and clear images in recognition test in Experiment 1.

Even though our findings aligned with the previous studies demonstrating a parallel recognition performance for disfluent and fluent images, we further elaborated on perceptual disfluency with multiple sources of perceptual manipulation in Experiment 2. In other words, blurriness as the sole source of manipulation could be inadequate to induce visual disfluency (Lindenberger et al., 2001), and thus, in Experiment 2, blurriness was coupled with inversion to further impede the visual acuity.

The inversion effect suggests that recognition of an item is more difficult when it is presented upside down than in its upright position (Kao, Chen & Chen, 2010). In this sense, Sungkhasettee, Friedman, and Castel (2011) demonstrated a superior free-recall performance for inverted words than upright words. Also, previous studies have reported that JOLs might cause a negative reactivity on actual recognition performances, meaning that recall performances are worse for judged items than non-judged items (Mitchium, Kelley & Fox, 2016). This means that taking immediate JOL ratings might confound actual recognition performance due to some other factors, such as increased retention time in the process of JOL decisions. Therefore, to eliminate the potential reactivity effect on actual recognition performance, subjects were not prompted with JOL ratings in Experiment 2.

Even with multiple sources of perceptual manipulations and eliminated JOL ratings, our results on actual recognition performances of blurred and inverted (disfluent) and clear (fluent) images were still similar in Experiment 2. To this end, one possible explanation for these findings might be that perceptual manipulations implemented in this study did not suffice to impair visual acuity. In other words, assuming that our task was within the limits of working memory capacity, inversion and blurriness together might also be insufficient to complicate the processing. Thus, subjects might have felt a similar ease of processing for both disfluent and fluent images, which resulted in almost identical recognition performance for both image forms. Another explanation

considering the ease of processing might be that matching alternatives of pictures at test might highly resemble the original pictures at encoding, which could lead to faulty recognition decisions among subjects. In other words, if studied and non-studied items were extremely hard to distinguish in Experiment 2, this could deceive them into making false recognition judgments about non-studied and studied items.

Besides the ease of processing of study and test items, another explanation for the results of Experiment 2 would be that the processing of disfluent and fluent images might be akin to each other regardless of the manipulation type, which resulted in parallel recognition performance for both forms. In fact, this is in line with previous studies, where subjects displayed comparable recognition performance for perceptually fluent and disfluent items even though disfluency was induced with a range of manipulations. Thus, it is possible that our results might simply replicate the notion that actual recognition performance was insensitive to perceptual fluency manipulations.

A final explanation of the comparable memory performances for disfluent and fluent images in Experiments 1 and 2 in our study might be the duration of the presentation. In this sense, Yue et al. (2913) elaborated on the effects of presentation time on memory performances. They found that even though blurred words consistently received lower JOLs than clear words across different presentation times, the memory performance for both forms of words converged as the duration of the presentation increased. In other words, while

recall performances were worse for blurred words in shorter presentation times (i.e., 0.5s and 2s), this distinction disappeared in extended presentation durations (i.e., 5s). Given that the presentation duration in our study in both experiments was even longer (i.e., 8s) than the longest presentation duration in this study (i.e., 5s), the comparable results might imply that our presentation duration was long enough to execute similar levels of processing for both disfluent and fluent images, which ultimately interfered the recognition performance between formats. Therefore, further studies with different encoding durations might be helpful in identifying whether comparable results in our study were due to presentation durations of study material.

4.3. Limitations and Recommendations for Future Studies

In this study, the blurriness was created by using the Gaussian Blur (Radius 10) filter of GIMP 2.10.32. This blur type was selected due to its resemblance to the natural deterioration of eyesight. Nonetheless, it might be possible that this type would be unsuccessful at interfering with visual acuity. In this sense, GIMP 2.10.32 offers a wide range of filters and alternative blur types that could be implemented on pictures to drive disfluency. Future studies might consider using one of the other blur types on GIMP 2.10.32 either alone or couple multiple blurrings or manipulation types (such as inversion and checkerboard) or simply change the Radius degree of Gaussian Blur to alter the processing of pictorial items.

Another notion that needs further adressing is a priori beliefs. Beliefs might substantially contribute to recognition performance as they might mediate the subjects' tendency to attend and encode an item. Therefore, future studies might include questionnaires on the a priori beliefs of subjects about the implications of the manipulation type implemented on pictures or measure the beliefs generated during the experiment at the end of the study.

Previous research has shown that encoding processes are influenced by presentation durations, which is illustrated by divergent recognition performance with varying presentation durations (i.e., 0.5s or 5s). Thus, further studies would help demonstrate whether actual recognition performance is primarily responsive to duration of presentation of a picture or manipulation type would interact with presentation durations.

Lastly, even though Experiment 1 of our study failed to show a perceptual fluency effect at encoding, past research about the perceptual-fluency hypothesis is often consistent. To avoid the confounds on actual recognition performances arising from JOL ratings, subjects were not prompted with JOLs in Experiment 2. Yet this leaves the subjects' metamemory judgments on blurred and inverted and clear images in Experiment 2 inconclusive. Hence, further studies are needed to explore the differential effects of perceptual fluency on metamemory judgments for blurred and inverted and clear pictures.

4.4. Practical Implications and Conclusions

In conclusion, this study demonstrated that neither metamemory judgments nor actual recognition memory performance was responsive to perceptual fluency manipulations even when multiple manipulations were incorporated. Although our results about actual recognition performance are parallel to previous findings, the results on metamemory judgments are contradictory to past research. Given that blurriness was scarcely used to drive disfluency in past research, the impact of blurriness as the main source of perceptual disfluency was elusive. In this sense, these results are particularly important in highlighting that blurriness might not be successful at inducing disfluency and should be approached with caution. On the other hand, even though inversion resulted in a greater recall performance in previous studies (Sungkhasette et al., 2011), the results of our study failed to find a divergent memory performance for fluent and disfluent items when inversion was implemented on pictures. Hence, these results point to the mixed effects of inversion, and whether inversion is a convenient manipulation of disfluency remains questionable.

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