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Age-Related Differences in Context-Specificity Benefits Ambiguous Predictive Learning

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AGE-RELATED DIFFERENCES IN CONTEXT-SPECIFICITY BENEFITS AMBIGUOUS PREDICTIVE LEARNING

A Capstone Project Presented in Partial Fulfillment

of the Requirements for the Degree Bachelor of Science

with Honors College Graduate Distinction at

Western Kentucky University

By

Catherine M. Luna

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CE/T Committee:

Professor Sharon Mutter, Chair

Professor Andrew Mienaltowski

Siera Bramschreiber

I dedicate this thesis to my parents, Kevin and Donna Woosley, who have always encouraged me to follow my passions and give my work my all. They have been my steadfast example of hard work and great love. I also dedicate this to my patient husband, Brian, who supports my every endeavor and daily reminds me to savor each moment with a cup of tea.

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I would like to thank all of the professors and peers who encouraged me to pursue the study of psychology. The graduate students who mentored me as an undergraduate research assistant in the Cognition Laboratory taught me the fundamentals of psychological research, the joys and struggles of daily progress in the lab. I would also like to extend a heart-felt thanks to all of the research assistants of the Cognition Laboratory who spent countless hours calling participants, scoring data, and making SPSS files. Finally, I offer my dearest gratitude to my research mentor and professional advisor, Dr. Sharon Mutter. All my thanks for tirelessly, and patiently, mentoring me into a psychologist in training. It is through the endless opportunities she has bestowed upon me that I have found my love for research, which does not culminate in, but rather begins with this thesis.

ABSTRACT

The present study investigated age differences in the context-specificity effect in learning. Ambiguity was manipulated in two conditions in a predictive learning paradigm (Callejas-Aguilera & Rosas, 2010) to encourage participants to attend to context. In the ambiguous condition, foods led to the presence of the illness equally as often as its absence. In the non-ambiguous condition, foods consistently led to the presence of the illness or consistently lead to its absence. Participants were instructed to make predictive judgments for foods leading to the presence of an illness in one of two restaurant contexts. During the test, participants made predictive judgments of food-illness associations in the same context as learned and in the different context. A context-specificity effect was observed if predictive judgments were higher for a food presented in the same context as learned than in the different context. Younger adults displayed a context-specificity effect in the ambiguous condition, but not in the non-ambiguous condition. Older adults did not display a context-specificity effect in either condition. Results are discussed with implications for the attentional theory of context processing (Rosas, Callejas-Aguilera et al., 2006) and the aging associative deficit.

VITA

Education (* denotes “in progress”)

Western Kentucky University (WKU)	M.S. in Psychological Sciences Concentration in Cognition	May 2018*
Western Kentucky University	B.S. in Psychological Sciences And in Music Honors College, Summa cum laude	May 2017*

Honors, Grants, and Scholarships

- JUMP Student in Psychological Sciences at WKU — March 2016
  - Accepted into the 5-year joint BS/MS degree program
- WKU Department of Psychological Sciences Academic Achievement Award — April 2016, 2017
- WKU President’s Scholar — May 2016, 2015, 2014
- WKU Founder’s Scholar — Granted May 2013
  - 4-year full-tuition scholarship, room and board scholarship, books stipend
- WKU Music Grant — April 2013,2014,2015,2016
  - $2,000 per year

Research Experience

National Science Foundation (NSF) June – August 2016

Research Experience in Undergraduates (REU)

Western Kentucky University

Responsibilities:

The REU was a 10-week program of intensive research working alongside Dr. Sharon Mutter on the role of context in predictive learning. I wrote a literature review on my topic, designed the experiment using SuperLab Pro, created a participant protocol script, ran participants, and statistically analyzed data. I also participated in weekly interactive workshops through which I wrote a research paper for the study. At the end of the program, I presented the study as a poster presentation at the program’s conference.

Research Laboratory Manager August 2016 – May 2018

Western Kentucky University

Responsibilities:

I managed multiple research experiments and trained undergraduate research assistants (URA) in Dr. Sharon Mutter’s Cognition Laboratory at WKU. As the research manager, I ensured that all participant contact, data collection, and statistical input was accomplished in a timely and professional manner. I trained all of the URA’s in standard laboratory procedures from confidentiality to scripted scoring and input of data.

Undergraduate Research Assistant August 2015-May 2016

Western Kentucky University

Responsibilities:

I worked under the graduate students in Dr. Sharon Mutter's Cognition Laboratory at WKU. I ran participants, scored data, ran statistical analyses on data, and entered participant information into the volunteer database for the two graduate student theses.

Presentations

Luna, C. W., Mutter, S., Lawrence, K., Cundiff, M., & Leucke, K. (April, 2017). *Ambiguity leads to context processing in predictive learning.* Oral presentation at the Student Research Conference at Western Kentucky University, Bowling Green, KY.

Luna, C. W., Mutter, S., Lawrence, K., & Cundiff, M. (March, 2017). *Ambiguity leads to context processing in predictive learning.* Poster presented at the Posters at the Capitol Conference in Frankfort, KY.

Brown, M., Mutter, S., Cundiff, M., Osbourn, M., & Woosley, C. (November, 2016). *Effects of age, task type, and information load on discrimination learning*. Poster presented at the Psychonomic Society's 57th Annual Meeting in Boston, MA.

Woosley, C., & Mutter, S. (August, 2016). *The effect of ambiguity on context in causal learning.* Poster presented at the REU Program Conference at Western Kentucky University, Bowling Green, KY.

Professional Affiliations

Association for Psychological Sciences (APS) August 2016 – Present

Golden Key Honor Society August 2014 – Present

Work Experience

Tutor January – December 2016

Kelly Autism Program

Western Kentucky University in Bowling Green, KY

Responsibilities:

I tutor and peer mentor for college students with Autism. I tutor students in general education courses and meet with a group of 5 students once a week for dinner to provide mentorship with social and emotional adjustment.

Music Private Lesson Teacher January – May 2016

Self-employed

Bowling Green, KY

Responsibilities:

I taught private violin lessons to collegiate and middle school students once a week. I assign each student weekly homework in technique and repertoire.

Sales Associate May 2014 – September 2016

Pier1Imports

Louisville and Bowling Green, KY

Responsibilities:

I provided customer service to satisfy daily customer needs. I also led seasonal product transformation teams and updated new displays because of my attention to detail.

Special Skills

- SPSS
  - Experience in statistical data analysis in SPSS.
- SuperLab Pro
  - Proficient in designing experiments in the computer software program of SuperLab Pro.
- Proficient in Microsoft Programs of Word, Powerpoint, and Excel
- Experience in technical writing of research manuscripts

Leadership and Volunteer Experience

Western Kentucky University Symphony August 2013 – Present

Violist in the Symphony

Responsibilities:

I am a violist in the WKU symphony. The ensemble rehearses three times a week during the school year, performing two to three concerts per semester. I have also participated in the production of two university operas in the pit orchestra.

Bridges Leadership Team May 2014 - December 2016

Bridges International at WKU

Responsibilities:

I serve on a team of eight students who plan weekly meetings and social activities to encourage relationships between American and International students of WKU. We also organize a weekend trip alternating between Louisville and Owensboro each semester. I am in charge of planning weekly discussion questions and formatting weekly meetings.

Honors College Ambassador May 2014 – August 2015

Honors College of WKU

Responsibilities:

I was an HonorsTopper, an ambassador for the WKU Honors College. I gave tours of the university to prospective students, and served at university events such as the Honors Round Table research conference and Super Saturdays sponsored by the WKU Center for Gifted Studies.

International Experience

Study Abroad in Salzburg Austria May – June 2015

Kentucky Institute for International Studies (KIIS)

Experience: I completed two music courses during a five-week program in Salzburg, Austria hosted by KIIS. Through this program I was able to grow in skills of autonomy, time management, and participate in cross-cultural engagement.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1

Introduction

All information is acquired in a context, whether that context is an emotional state, an odor, or physical surrounding. The influence of context on learning and memory has intrigued researchers for decades. When information becomes associated with its context during learning, it exhibits a ‘context-specificity effect’. Specifically, the information or a response associated with the information is more accurately retrieved in the context where the information was acquired, than in a different context.

The operational definition of context varies depending on the topic of interest. Early memory research defined context as the physical environment surrounding an individual (Smith, 1979). However, context can also be considered in the broader sense as the incidental background related to the individual or the primary stimuli in a task (Smith, 1994). Incidental contexts are not explicitly cued by the researcher. Under these conditions, the context may not receive overt attention, but it can be implicitly associated with the primary stimuli to modify responses (Smith, 1994). This property was called “occasion setting” by Holland (1992), who suggested that when the context is reinstated, the context “sets the occasion” for an individual to produce the response associated with that context (Urcelay & Miller, 2014). The use of incidental contexts, therefore, allows researchers to covertly study the context-specificity effect using learning paradigms without explicit instruction.

The context-specificity effect has been extensively studied in memory and learning with young adults, but it is insufficiently represented in aging research. This under-representation is particularly prominent in learning research. The current study will consider how aging might affect context-specificity effects in an associative learning paradigm.

Memory and the Context-Specificity Effect

Research on the context-specificity effect in memory began using reinstatement paradigms. In the seminal study of context-dependent memory (a term used to refer to the context-specificity effect exclusively in memory research), scuba divers learned a word list either under water or on land (Godden & Baddeley, 1975). The divers then recalled the word list either in the same environment as learned or in the other environment. Divers whose memory for the word list was tested in the same environment as learned (e.g., learn under water, recall under water) recalled more words than those in the different environment (e.g., learn under water, recall on land). This phenomenon was called the "environmental reinstatement effect" (Smith, 1979), because the reinstatement of the learning environment led to an increase in recall. Likewise, the switch in the learning environment led to a decrease in recall. This showed that retrieval of information was dependent upon the reinstatement of the context.

Later research investigated how variations of context affected context-dependent memory. Some studies showed that reinstatement of the entire context was not always necessary to observe context-dependent recall. A simple cue to imagine the learning environment led to the same results as the complete reinstatement of the environment (Smith, 1979). Recall accuracy increased when individuals were instructed to mentally picture the context, even though they were not in the physical environmental context from the learning phase. In recognition memory, the reinstatement effect extended beyond physical cues to semantic cues. When the semantic interpretation of a phrase was different at test than it was in the learning phase, then individuals recognized significantly fewer phrases (Light & Carter-Sobell, 1970). This replicated the effects of context-dependent memory, but extended the definition of context beyond a physical environment to the effect of semantic context on the interpretation of the to-be-remembered stimulus. These studies suggest that context can be defined broadly and that context-dependent memory can be influenced by a variety of contextual cues.

The majority of research on context-dependent memory has used recall or recognition tests and produced reliable, yet small, effect sizes (Smith & Vela, 2001). However, it is important to note that the environmental reinstatement effect does not always occur. In a follow-up investigation of the seminal scuba diver study, Godden and Baddeley (1980) did not observe a significant effect of context-dependent memory with a recognition test instead of a recall test. Context-dependent memory may rely more heavily on whether the contextual cue is needed to help retrieve a memory than on the mere presence of context. In recognition, the target information is present and is the best cue, so contextual cues may not be necessary. Context-dependent memory was observed with a semantic recognition test because the meaning of the context cue at retrieval biased a different meaning for the target (Light & Cater-Sobell, 1970). See these reviews for more information on context-dependent memory (Isarida & Isarida, 2014; Smith, 2013).

Associative Learning and the Context-Specificity Effect

The context-specificity effect has also been investigated in learning using an extinction paradigm. Bouton and Bolles (1979) began the research on context-specificity in extinction training following classical and operant conditioning with rats. In extinction, a cue is not followed by the outcome with which it was originally associated. After responses to the cue decrease, reinstatement can be implemented by presenting a single trial where the cue is followed by the original outcome. Both extinction and reinstatement can be context-specific (Bouton, 1994). If learning occurs in context A and extinction occurs in context B, then the subject will exhibit a reinstated response to the cue in context A. In fear conditioning paradigms, a cue from the extinction context presented in the reinstatement context leads to a decrease in responding (Dibbets et al., 2008). Thus, a cue from the extinction context produces the response learned in that context. This effect occurs reliably in both animals (Bouton & Bolles, 1979; Bouton & Ricker, 1994; Harris, Jones, Bailey, & Westbrook, 2000) and humans (Dibbets, Havermans, & Arntz, 2008; Labar & Phelps, 2005; Nelson, Lamoureux, & Leon, 2013).

Extinction training with humans has used predictive learning tasks. The predictive learning paradigm allowed researchers to both analyze the fundamental processes involved in contextual learning and link the animal extinction studies with human studies on context-specificity (Dibbets, Maes, Boermans, & Vossen, 2001). Predictive learning requires that participants learn the likelihood of a specific cue leading to the presence or absence of an outcome (i.e. cue-outcome associations). Because the cue-outcome associations are the primary focus of the task, all other stimuli are contextual cues. The context-specificity effect occurs when participants give lower predictive judgments for a cue-outcome association if the contextual cues that were present when the association was learned are absent at the test. Through the predictive learning paradigm, specific aspects of the contextual cues and/or the primary stimuli in the learning trials can be manipulated to establish consistent contributors to the context-specificity effect.

Context effects in extinction have been explained by an attentional theory of context processing (Rosas, Callejas-Aguilera, Alvarez, & Abad, 2006), which suggests that causing an individual to pay attention to context promotes the formation of an association between the information and the context. Once this association is formed, then the reinstatement of the context will produce the response formerly learned in that context or a higher level of performance on the task learned in that context. Causing an individual to pay attention to context can be accomplished by manipulating attributes of the learning environment. One of these attributes is ambiguity. For example, in extinction training cues previously learned as strong cue-outcome associations are no longer followed by the outcome, and so the meaning of the cue becomes uncertain. The ambiguous nature of the cue-outcome associations in extinction leads subjects to attend to context (Nelson et al., 2013). Partial reinforcement is a form of extinction in which a cue equally leads to the presence of the outcome or the absence of the outcome. Continuous reinforcement, its counterpart, exists when a cue consistently leads to the presence or consistently leads to the absence of the outcome. Partial reinforcement creates ambiguity, but continuous reinforcement is unambiguous (Rosas, Todd, & Bouton, 2013). By manipulating the use of partial and continuous reinforcement in predictive learning, the level of ambiguity and how much one attends to context in a predictive learning paradigm can be manipulated.

According to the attentional theory of context processing, once one pays attention to context during learning, all of the information acquired in that context becomes context-specific (Rosas, Callejas-Aguilera, et al., 2006). The presence of ambiguity, or uncertainty, during learning causes participants to pay more attention to the ambiguous cues (Hogarth, Dickinson, Austin, Brown, & Duka, 2008). In an attempt to disambiguate these cues, participants then shift their attention from the primary cue-outcome association to contextual cues that could potentially provide information about the outcome (Rosas, Garcia-Gutierrez, & Callejas-Aguilera, 2006).

When contextual cues are associated with or linked to the primary cue-outcome association, then the presence of the contextual cues modulates the outcome response (De Houwer, 2014; Leon, Abad, & Rosas, 2008). This modulation occurs because the relational value of the contextual cues to the primary cue-outcome associations causes participants to selectively attend to the most informative attributes of contextual cues for predicting the outcome (George &

Kruschke, 2012; Uengoer, Lochnit, Lotz, Koenig, & Pearce, 2013). As learning trials increase in unambiguous tasks, participants cease to attend to context (Leon et al., 2010, 2011). However, the general presence of ambiguity produces context-specificity for all information presented in a predictive learning task. Specifically, the presence of some ambiguous cue-outcome associations in the task leads to even unambiguous cue-outcome associations becoming context-specific (Rosas, Garcia-Gutierrez, et al., 2006, Rosas & Callejas-Aguilera, 2006).

Methodological advances. A combination of methodological designs is essential for the best procedure to analyze context-specificity during learning. The simultaneous use of unambiguous continuous and ambiguous partial reinforcement in predictive learning provides the basic framework for studying context-specificity. Analyzing context-specificity between-subjects allows one to compare the overall effects of varying levels of context-specificity inducing attributes, such as ambiguity (Leon et al., 2008, 2010); however, an individual's modulating response to the same and different contexts cannot be analyzed. Within-subject context-specificity gives participants equal exposure to each context and reveals the differential response of an individual when a cue is presented in the same context as learned and in a different context than learned (Dibbets et al., 2001; George & Kruschke, 2012; Leon et al., 2011).

Callejas-Aguilera and Rosas (2010) created a mixed-factorial predictive learning paradigm, in which levels of ambiguity were manipulated between-subjects to moderate context-specificity. Relational value between context and primary cue-outcome stimuli was enhanced by using a restaurant context, food-illness scenario. Compound cue-outcome associations were continually or partially reinforced to manipulate the amount of ambiguity in the learning context, whereas continuously reinforced single cue-outcome associations were tested. Context was manipulated within-subjects, by exposing participants to two contexts equally in training, and then testing them on target single cue-outcome associations learned in the same or the switched context. In two experiments, a context-specificity effect was displayed in the ambiguous condition; i.e., participants rated predictive judgments for target single cues lower when presented in a different context than learned. The ambiguity of the compound cues led participants to attend to context, so that all the compound and single cues became context-specific. This ambiguity-related context-specificity effect supported the attentional theory of context processing (Rosas, Callejas-Aguilera, et al., 2006).

Aging and Context-Specificity

Considerable research on aging memory suggests that older adults fail to show context-specificity effects. This is thought to be caused by an age-related associative deficit. In visual working memory tasks, older adults exhibit deficits in item-context binding (Peterson & Naveh-Benjamin, 2016) and the maintenance of context (Braver et al., 2001). Item-context binding refers to the additional association of the cue with its context, such as spatial location. In tasks not requiring much cognitive load, older adults may perform comparably to younger adults for the basic cue-outcome association (Mutter & Asriel, 2016), but older adults will not exhibit any additional item-context binding (Kessels, Hobbel, & Postma, 2007). Furthermore, older adults struggle to maintain contextual information throughout a task (Braver et al., 2001). These deficits have been supported by research in environmental context-dependent memory in aged rats and aged humans, suggesting that older subjects do not use contextual cues to inform responses in a recall test (Jones, Pest, Vargas, Glisky, & Fellous, 2016). Age-related deficits in item-context binding and the maintenance of context support observations that older adults struggle to bind multiple cues in memory (Kessels et al., 2007).

Though the associative binding deficit is known to affect item-context binding in memory, there is little research on aging and context-specificity in a predictive learning paradigm. In the animal learning literature, age-related deficits in the context-specificity of learned information have been seen in extinction training with aged rats (Wiescholleck, André, & Manahan-Vaughan, 2014). Moreover, studies of predictive learning with older adult humans support the age-related associative binding deficit commonly observed in memory research (Mutter & Plumlee, 2009, 2014). However, there have been no studies of aging and context-specificity in predictive learning. The lack of context-specificity observed in extinction for aged animals, along with the associative binding deficits observed in human predictive learning suggest that older adults may not display a context-specificity effect in predictive learning.

Summary, Implications, and Discussion

In summary, the context-specificity effect has been studied in both memory and learning, but its effects are not as well understood in older adults' learning. The memory literature suggests that reinstatement of contextual cues can modify an individual's responses in recall and recognition. The predictive learning studies show that partial reinforcement creates ambiguity during learning, which causes individuals to attend to context. Researchers have investigated ambiguity's influence on context-specificity in young adults' learning using mixed-factorial designs, but this methodology has yet to be studied with context-specificity in older adults' learning. The age-related associative binding deficit leads to an inability to produce item-context binding; therefore, older adults often do not exhibit context-specificity effects.

The primary goal of this study was to assess whether there are age differences in the context-specificity effect in predictive learning. To do this, we tested younger and older adults using the ambiguous predictive learning task developed by Callejas-Aguilera & Rosas (2010).

We hypothesized that younger adults would show a context-specificity effect in conditions with ambiguity, but not in unambiguous conditions. In contrast, we expected that because of an inability to bind context with the cue-outcome associations, older adults would not show context-specificity even in an ambiguous condition.

Chapter 2

Method

Design and Participants

The design of the study was a 2 (age group: younger vs. older) X 2 (condition: no ambiguity vs. partial ambiguity) X 2 (context: same vs. switched) X 2 (target cue: C1 vs. C2) mixed factorial. Age group and condition were between-subjects factors. Context and target cues were within-subjects factors. The dependent variable was predictive judgments of the target cues leading to the presence of a gastric illness. This study was approved by the Human Subjects Review Board of Western Kentucky University (WKU) in May 2016.

Thirty-two younger adults (age 18 to 30) and thirty-six older adults (age 60 to 85) were recruited for the study. Younger adults were recruited from Western Kentucky University via an online university study board and on-campus flyers. Study board credit or a small monetary stipend were given as compensation for participation. Three younger adults failed to pass the discrimination learning criteria and were excluded from all analyses (discussed in the Results section). Older adults were recruited from the local community via the voter registration, community flyers, and participation in other institutional studies. A small monetary stipend was given as compensation for participation. Five older adults failed to pass the discrimination learning criteria and were excluded from all analyses.

Exclusion criteria for study participation were non-native English speakers and color-blindness (screened by Ishihara's Tests for Colour Deficiency – Concise Edition). One younger adult was excluded from participation for failing to pass the color-blindness screening. In addition to the primary exclusion criteria, older adults were screened for pre-existing cognitive impairment using the Telephone Mini-Mental State Examination (TMMSE) before participation. All older adult participants passed the TMMSE with at least 17 out of 21 correct answers for the general cognitive deficit screening. Biographical characteristics and cognitive data are presented in Table 1.

Table 1. *Participant Characteristics*

Group	Younger	Older
N	28	31
Age (years)	20.07 (2.04)	68.84 (4.65)
Education (years)	14.11 (1.84)	16.48 (2.91)
Ishihara	10.96 (0.19)	10.94 (0.36)
Advanced Vocabulary**	13.54 (5.81)	20.44 (7.99)
Reading Span	2.86 (1.33)	2.64 (2.92)
DS substitution**	80.71 (11.65)	60.71 (12.05)
DS incidental learning	23 (5.10)	21.13 (4.50)
CAL % forgotten**	2.75 (2.38)	5.20 (2.10)
CAL % perseverations*	1.61 (2.30)	3.10 (2.87)
WCST categories completed**	3.96 (1.14)	2.30 (1.53)
WCST % perseverative errors**	7.82 (3.43)	11.69 (6.59)

Note. Standard deviations are in parentheses. * indicates significant group difference at $p < .05$. ** indicates significant group difference at $p < .01$. Ishihara = Ishihara's Test for Colour Deficiency – Concise Condition (Isshinkai Foundation, 2006); Advanced Vocabulary (Ekstrom, French, & Harman, 1979); Reading Span (Salthouse & Babcock, 1991); DS = Digit Symbol (Wechsler, 1997); CAL = Conditional Associative Learning (Levine, Stuss, & Milberg, 1997); WCST = Wisconsin Card Sorting Task (Heaton, Chelune, Talley, Kay, & Curtiss, 1993).

Stimuli and Materials

The predictive learning task used a restaurant food-illness association paradigm (Callejas-Aguilera & Rosas, 2010). The task was programmed on a Macintosh computer using the software program SuperLabPro 4.5. Participants were told that they would learn to predict whether foods would lead to the presence (+) or absence (-) of an illness. Each food-illness association was presented in one of two restaurant contexts (A, B). The food cues, X, Y, Z, C1 and F were presented in Context A. The food cues W, H, R, C2 and F were presented in Context B. XY and XZ were combined and presented as compound cues for Context A, and WH and WR were combined and presented as compound cues for Context B. The food cues C1, C2 and F remained as single food cues. The food cues C1 and C2 served as target cues in the test of the context-specificity effect. See Table 2 for a concise display of the experimental design.

The presence of an illness was stated as “DIARRHEA” and the absence was “NOTHING.” The two restaurant contexts were counterbalanced over participants as “The Canadian Cabin” and “The Swiss Chalet.” Food stimuli were randomly selected from an American food index categorized by typicality (Mutter & Asriel, 2016). The letters X, Y, and Z were counterbalanced over participants as food cues “PEAR,” “BROCOLLI,” and “STEAK.” The letters W, H, and R were counterbalanced over participants as food cues “SALMON,” “BANANA,” and “LETTUCE.” The filler cue, F, was always “TUNA.” The target cues, C1 and C2, were counterbalanced over participants as “CHICKEN” and “CELERY.”

Ambiguity was manipulated in two conditions. In true discrimination (TD), cues were continuously reinforced, so there was no ambiguity. For example, XY always led to the illness, and XZ always led to nothing. In pseudo discrimination (PD), cues were partially reinforced, inducing ambiguity; i.e., both XY and XZ led to the presence of the outcome equally as often as the absence of the outcome. In the TDTD condition all single and compound cues were continuously reinforced in both contexts. In the PDTD condition, compound cues were partially reinforced in Context A and continuously reinforced in Context B. All single cues were continuously reinforced in each context of each condition.

The learning trials were divided among 3 blocks in each context. In the TDTD condition, the cues XY+, XZ-, C1+, and F- were presented four times in each block of Context A. The cues WH+, WR-, C2+ and F- were presented four times in each block of Context B. In the PDTD condition, the cues XY+, XY-, XZ+, and XZ- were presented twice in each block of Context A. All other food cues in the PDTD condition were presented four times in each block. The numbers in the Learning column of Table 1 indicate the minimum number of trials of each food-illness association each participant received. Participants who were unable to learn the cue – outcome relationships to a criteria of a minimum difference of 50 in predictive judgments of single food cues (further explained in Results) were given two additional learning blocks in each context. All young adults learned within three blocks in each context. Seven older adults (5 TDTD, 2 PDTD) learned within three blocks in each context. The remainder of the older adults (10 TDTD, 14 PDTD) learned within five blocks in each context.

The order of the trials within each block was randomized for each participant. The block order was counterbalanced between-subjects as ABBAAB, and BAABBA.

Table 2. *Experimental Design*

Condition	Pre-test	Learning	Test
TDTD	X?, Y?, Z?, W?, H?, R?, F?, C1?, C2?	A: 12XY+, 12XZ-, 12C1+, 12F- B: 12WH+, 12WR-, 12C2+, 12F-	A: C1?, C2? B: C1?, C2?
PDTD		A: 6XY+, 6XY-, 6XZ+, 6XZ-, 12C1+, 12F- B: 12WH+, 12WR-, 12C2+, 12F-	A: C1?, C2? B: C1?, C2?

There were two primary screens for the learning phase: the stimulus screen, and the feedback screen. The stimulus screen was arranged as follows. The upper left of the screen presented the context introduction, “One person ate at….” The upper middle of the screen presented the respective context, either “The Swiss Chalet” in a yellow oval, or “The Canadian Cabin” in a turquoise rectangle. Both contexts were in 36 point, blue font. The middle left of the screen presented the food introduction, “This person ate ….” The center of the screen presented the food or compound food pairing in all-uppercase, 48 point, blue font. The rating scale introduction, “Click here to indicate the probability that this person had diarrhea,” was in the bottom center of the screen in 36 point font. Beneath this was a rating scale with 21 green buttons equally spaced on a 0-100 scale. The labels “Definitely Not, Probably Not, Maybe, Probably, and Definitely,” were equally spaced beginning above 0 and ending above 100. When the participant clicked a green button on the rating scale, the feedback screen appeared. The feedback screen showed the respective context in the same position as on the stimulus screen. In the middle left of the screen read the feedback intro, “This person had….” The center of the screen read the respective outcome of DIARRHEA in 48 point, red font, or NOTHING in 48 point, green font. The feedback screen appeared for 1,500 ms.

The test consisted of four screens. The order of the test screens was counterbalanced from the learning block order, so that in learning order ABBAAB, the test screens were BBAA. Each target food cue (C1 and C2) was presented in each context, so that each target food cue was tested in the same context as learned and in the switched context. The order of the target cue presentation was randomized within each context. The test screens appeared identical to the learning phase screens, except no outcome feedback was provided.

Procedure

Participants in each age group were randomly assigned to the TDTD or PDTD conditions and to a block order. In the younger adult group, there were 15 participants in the TDTD condition, and there were 13 participants in the PDTD condition. In the older adult group, there were 15 participants in the TDTD condition, and there were 16 participants in the PDTD condition. Participants completed the research procedure individually in the Cognition Laboratory at WKU. The entire procedure lasted no longer than two hours. Upon entering the laboratory, the participant read and signed an informed consent document. Next, the participant was screened for color-blindness by Ishihara's Tests for Colour Deficiency: Concise Edition (2006). Contingent upon passing this screening, the participant completed a biographical and health questionnaire containing items on demographics and health history. Next, the participants completed the experimental task.

For the predictive learning task, participants sat in front of a computer and the experimenter sat to their left. The experimenter read the instructions aloud while the participants read them silently. There were four instruction screens, which created the background scenario for the task. Participants were told they would view food(s) presented in different restaurants and that they should learn the probability that the food(s) would lead to diarrhea. The full instructions are provided in Appendix 1. Following the instructions, the experimenter demonstrated a practice trial in the learning phase of the task. The practice trial was the same as the learning trials, except the arbitrary cue of "The Lakeview Lodge" in a magenta box and the food cue of "PASTA" was used. The experimenter selected the predictive judgment of "50" on the rating scale. The feedback screen for the practice trial showed "The Lakeview Lodge" context and that the person had "DIARRHEA."

Participants then took a pre-test to measure pre-existing biases for the nine food cue's association with diarrhea. The first screen of the pre-test stated, "Before starting, please answer these questions." To advance to the next screen, the participant clicked a yellow rectangular button with the phrase, "Click here to continue," in 36 point, blue font, located in the bottom right corner of the screen. Food cues were then presented individually in the center of the screen without a context. Participants made a predictive judgment on the rating scale indicating the degree they believed the stated food would lead to diarrhea. No outcome feedback was provided.

The learning phase followed the pre-test. The first screen of each block in the learning phase appeared for 1,500 ms. and stated, "Now you should analyze the files of people who ate at restaurant…" with the new restaurant context in the center of the screen. Each learning trial consisted of three screens: file name screen, stimulus screen, feedback screen. The file name screen read, "Loading file of …" followed by a person's name for 1,500 ms. All names were selected from an online random name generator. This screen was used to inform the participant that all cue-outcome associations were different cases and served as an intertrial interval. During the stimulus screen, the participant saw the food cue and made a predictive judgment of the probability that the food would lead to diarrhea. After the participant made the predictive judgment, the feedback screen automatically displayed the appropriate outcome for the previous food cue for 1,500 ms. Then, the next trial immediately began.

After the completion of the learning blocks, the participants received a test. It began with a screen stating, "Please, answer this question." Then the participants made predictive judgments for the target cues (C1, C2) in both the same context (SAME) as learned and in the other context (SWITCHED). No feedback was given.

After completing the predictive learning experimental task, participants completed the following individual differences tests: Digit Symbol Substitution Test and Digit Symbol Incidental Learning (IL), Wisconsin Card Sorting Task (WCST), Reading Span, Advanced Vocabulary (AV), and the Conditional Associative Learning test (CAL). These were administered to ensure the sample was representative of the populations for the two age groups. Participants were allowed a five-minute break between WCST and Reading Span. Upon completion of the last task, the experimenter read a scripted debriefing statement to the participants. Then the participants were compensated for their time in the laboratory.

Chapter 3

Results

To ensure all participants included in the results analyses accurately learned the target cue food-illness discriminations, a learning criteria was computed. The learning criteria was a mean predictive judgment difference of greater than or equal to 50 between the target cues, C1 and C2, and the filler cue F in the final block of learning in each context. Thus, the difference was calculated between the mean predictive judgments of C1+ and F- in Context A, learning block 3 (for younger adults) or 5 (for older adults). Then, the difference was calculated for C2+ and F- in Context B, learning block 3 or 5. If a mean predictive judgment difference was less than 50 in either context, the participant's data were excluded from further analyses. Four younger adults (1 TDTD; 3 PDTD) and five older adults (3 TDTD; 2 PDTD) were excluded based on these criteria.

All statistical analyses were computed using mean predictive judgment ratings as the dependent variable. The analysis of variance (ANOVA) model was used with the criterion of significance set at $p \leq .05$.

Pre-test Phase

To assess pre-existing food biases, young and older adults' mean predictive judgment ratings (± standard errors of the mean) for each food cue presented in the pre-test were calculated. Younger adults tended to rate the probability of illness higher for meats and seafoods than fruits and vegetables (CHICKEN: 50.36 ± 4.36; SALMON: 52.14 ± 4.3; STEAK: 53.75 ± 4.38; TUNA: 49.46 ± 4.43; BANANA: 27.5 ± 3.45; BROCCOLI: 33.75 ± 4.07; CELERY: 28.93 ± 4.66; LETTUCE: 26.43 ± 4.15; PEAR: 25 ± 3.91). Older adults tended to rate the probability of illness higher for meats, seafood, and green vegetables than fruits (CHICKEN: 45.81 ± 2.68;

SALMON: 46.3 ± 2.82; TUNA: 45.48 ± 2.79; STEAK: 39.19 ± 3.08; LETTUCE: 44.84 ± 3.88; BROCCOLI: 43.39 ± 3.65; CELERY: 30.16 ± 3.41; BANANA: 37.74 ± 3.63; PEAR: 36.13 ± 3.16). However, the food cues of primary interest were CHICKEN and CELERY because these foods were the target food cues for the test. Both age groups consistently rated CHICKEN higher than CELERY, but the foods were counterbalanced across the test cues so that each food was target C1 equally as often as target C2. A 2 (Group) x 2 (Pre-test C1 and C2) ANOVA revealed no significant interactions of group differences between pre-test predictive judgments of these two target cues, $F(1,57) = 3.614$, $\eta_p^2 = .060$. No main effects were significant either [Pre-test cue: $F(1,57) = .122$, $\eta_p^2 = .002$; Group: $F(1,57) = .19$, $\eta_p^2 = .003$].

Learning Phase

Compound cue and single cue learning trials were analyzed separately. Ambiguity was only manipulated in compound cues, so their learning data was analyzed for discrimination differences between continually reinforced and partially reinforced compound cues. In the compound cue learning trials, XY and WH were analyzed as compound 1, and XZ and WR were analyzed as compound 2. For condition PDTD, predictive judgments were averaged for compound cues XY+ and XY- to create the variable XY+/-, and likewise for compound cue XZ. Single cue learning trials were evaluated to determine the accuracy of discriminating the target cues (C1 and C2) as high predictors of the outcome. In single cue learning trials, C1 and C2 were analyzed as cue 1, and F was analyzed as cue 2.

Due to the greater number of learning blocks for older adults, learning phase analyses were conducted using the mean predictive judgment ratings from the end of the first block of trials and the end of the last block of trials for each participant. Thus, younger adult analyses included mean predictive judgments from block 1 and block 3 of each condition and each context, and older adult analyses included mean predictive judgments from block 1 and block 3 or 5 of each condition and each context.

Figures 1 and 2 show the mean predictive judgments of younger adults and older adults, respectively, for the compound cues across blocks. Figures 3 and 4 show the mean predictive judgments of younger adults and older adults, respectively, for the single cues across blocks.

Compound cue learning trials. A 2 (Group) x 2 (Condition) x 2 (Context) x 2 (Compound) x 2 (Block) ANOVA revealed a significant four-way interaction of Group x Condition x Context x Compound, $F(1,55) = 4.58$, $\eta_p^2 = .037$, and two significant three-way interactions of Condition x Compound x Block, $F(1,55) = 31.208$, $\eta_p^2 = .362$, and Context x Compound x Block, $F(1,55) = 14.035$, $\eta_p^2 = .203$. (See Table 3 for all main and interaction effects.) Further analysis of the four-way interaction isolated group. There was a significant three-way interaction of Condition x Context x Compound in both groups [younger adults: $F(1,26) = 35.618$, $\eta_p^2 = .578$; older adults: $F(1,29) = 6.022$, $\eta_p^2 = .172$], but the effect size was greater for the younger adults. In the younger adult group, the two-way interaction of Context x Compound was not significant in condition TDTD, $F(1,14) = .227$, $\eta_p^2 = .016$, but there was a significant two-way interaction of Context x Compound in condition PDTD, $F(1,12) = 56.343$, $\eta_p^2 = .824$. The main effect for compound was not significant in context A of PDTD in the younger adult group, $F(1,12) = 3.12$, $\eta_p^2 = .211$, but the main effect for compound was significant in context B, $F(1,12) = 49.251$, $\eta_p^2 = .804$. This suggests that younger adults discriminated the compound cues in the TDTD condition and in context B of the PDTD condition, but did not discriminate the compound cues (XY+/-, XZ+/-) in context A of the PDTD condition (see Figure 1).

In the older adult group, the two-way interaction of Context x Compound was not significant in condition TDTD, $F(1,14) = 2.308$, $\eta_p^2 = .142$, but there was a marginal two-way interaction in condition PDTD, $F(1,15) = 3.946$, $\eta_p^2 = .208$, $p = .066$. This interaction is marginally significant because, unlike the younger adults, older adults showed less discrimination between the compound cues (WH, WR) in context B of PDTD than in context B of TDTD. Nevertheless, older adults showed the same discrimination trends as the younger adults (see Figure 2).

In further analysis of the three-way interaction of Condition x Compound x Block, there was a significant two-way interaction of Compound x Block in both conditions [condition TDTD: $F(1,29) = 119.997$, $\eta_p^2 = .805$; condition PDTD: $F(1,28) = 13.229$, $\eta_p^2 = .321$], but the effect size was larger in condition TDTD. In condition TDTD, the main effect of block was significant for both compound 1, $F(1,29) = 85.75$, $\eta_p^2 = .747$, and compound 2, $F(1,29) = 80.165$, $\eta_p^2 = .734$. In condition PDTD, the main effect of block was significant for compound 1, $F(1,28) = 24.46$, $\eta_p^2 = .466$, but it was not significant for compound 2, $F(1,28) = 1.552$, $\eta_p^2 = .053$. This shows that younger and older adults in the TDTD condition discriminated the compound cues across block better than the younger and older adults in the PDTD condition.

In further analysis of the three-way interaction of Context x Compound x Block, the Compound x Block interaction was significant in both contexts [context A: $F(1,58) = 22.523$, $\eta_p^2 = .280$; context B: $F(1,58) = 107.884$, $\eta_p^2 = .65$], but the effect size was greater in context B. In context A, the main effect of block was significant for both compounds [compound 1: $F(1,58) = 27.981$, $\eta_p^2 = .325$; compound 2: $F(1,58) = 6.018$, $\eta_p^2 = .094$], but the effect size was greater for compound 2. In context B, the main effect of block was significant for both compounds [compound 1: $F(1,58) = 86.262$, $\eta_p^2 = .598$; compound 2: $F(1,58) = 49.46$, $\eta_p^2 = .46$], with a slightly larger effect size in compound 1. This indicates that over learning blocks, participants of both groups discriminated outcomes better for the compound cues of context B than context A.

Figure 1. Mean Predictive Judgments of Younger Adults for Compound Cues

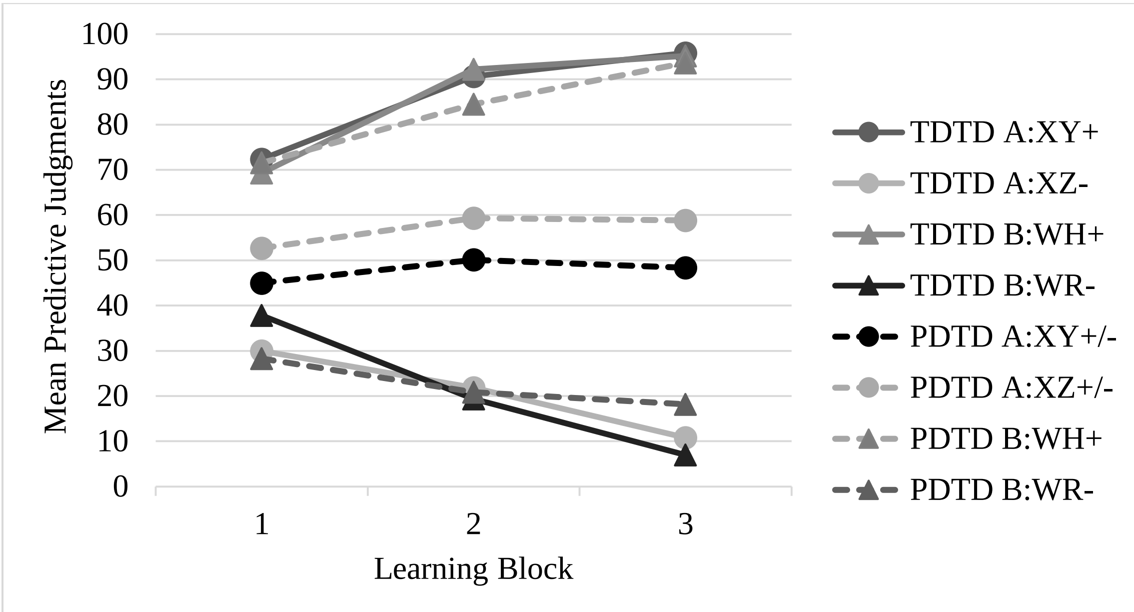
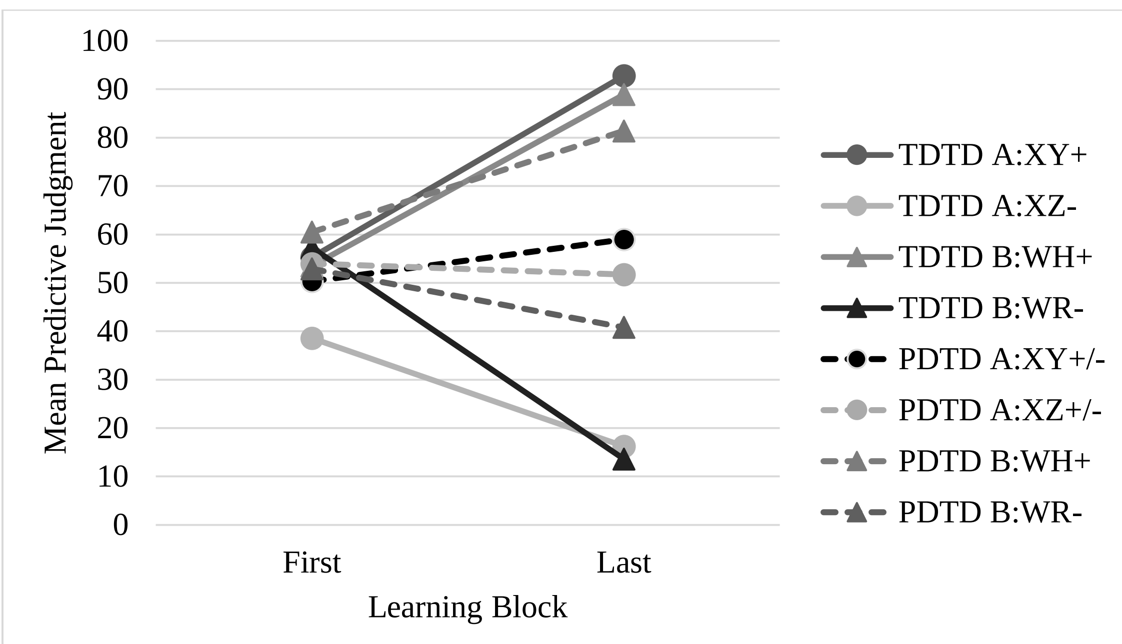


Figure 2. Mean Predictive Judgments of Older Adults for Compound Cues



Single cue learning trials. A 2 (Group) x 2 (Condition) x 2 (Context) x 2 (Cue) x 2 (Block) ANOVA revealed significant three-way interactions of Group x Context x Cue, $F(1,55) = 5.729$, $\eta_p^2 = .094$, and Group x Cue x Block, $F(1,55) = 10.343$, $\eta_p^2 = .158$. (See Table 4 for all main and interaction effects.) To analyze the three-way interaction of Group x Context x Cue, we isolated group. There was a significant main effect of cue for both groups [younger adults: $F(1,27) = 823.845$, $\eta_p^2 = .968$; older adults: $F(1,30) = 331.097$, $\eta_p^2 = .917$]. There were no significant main or interaction effects including context. This shows that participants of each group were able to discriminate between the single cues in each context. The interaction shows that older adult mean predictive judgments for the positively reinforced cues of context A (C1) and context B (C2) were less discriminated than younger adult mean predictive judgments of these cues (see Figure 3 and Figure 4).

To analyze the three-way interaction of Group x Cue x Block, we isolated group. There was a significant two-way interaction of Cue x Block for both groups [younger adults: $F(1,27) = 159.137$, $\eta_p^2 = .855$; older adults: $F(1,30) = 296.275$, $\eta_p^2 = .908$]. The main effect of block remained significant in each group even when cue was isolated. This indicates that all participants acquired the discrimination of singles cues across blocks, but the younger adults began to acquire this discrimination by the end of the first block, while the older adults did not (see Figure 3 and Figure 4).

Figure 3. Mean Predictive Judgments of Younger Adults for Single Cues

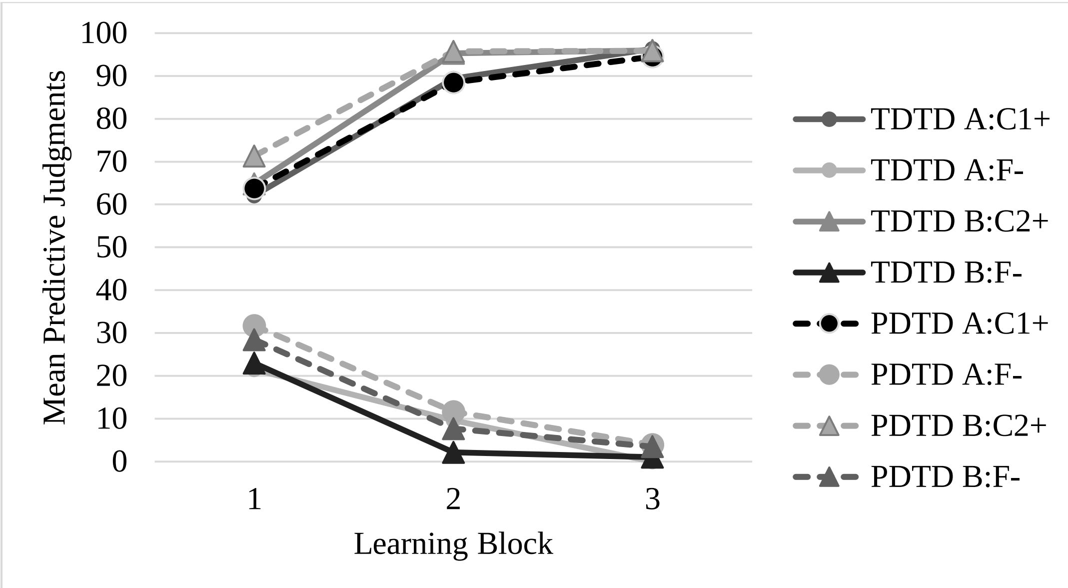
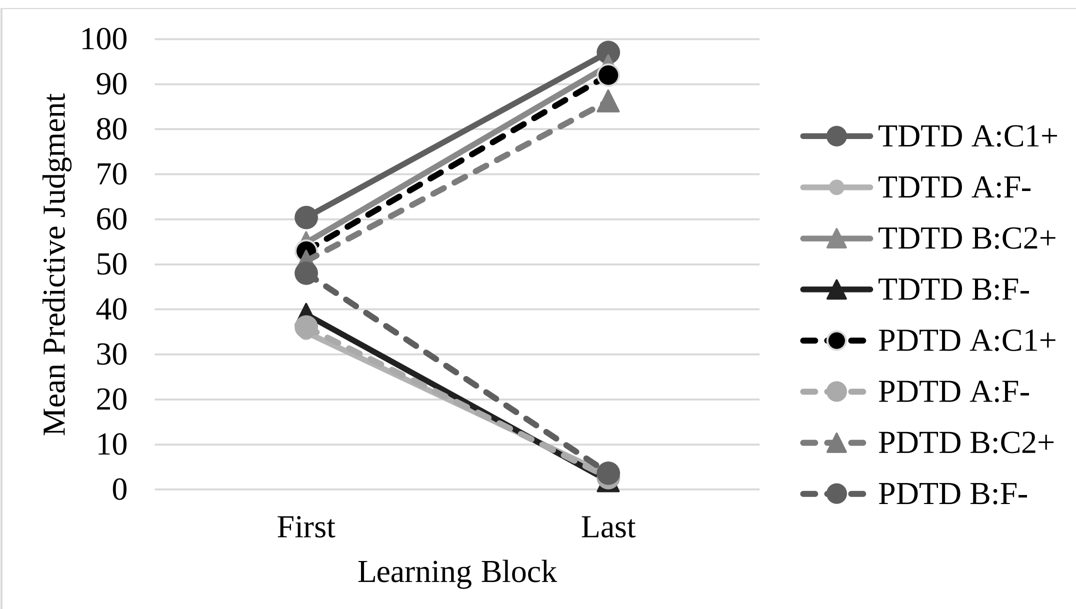


Figure 4. Mean Predictive Judgments of Older Adults for Single Cues



Test Phase

Mean predictive judgments for target cues (C1, C2) were assessed in the same context as learned and in the other context. Figure 5 displays the mean predictive judgments of target cues in the same and switched contexts for condition TDTD for each group. Figure 6 displays the mean predictive judgments of target cues in the same and switched contexts for condition PDTD for each group. A 2 (Group) x 2 (Condition) x 2 (Target Cue) x 2 (Context) ANOVA revealed a significant two-way interaction of Context x Group, $F(1,55) = 10.164$, $\eta_p^2 = .156$. (See Table 5 for all main and interactions effects.) For younger adults, there was a significant main effect of context, $F(1,27) = 12.915$, $\eta_p^2 = .324$, but the effect of context was not significant in the older adult group, $F(1,30) = 1.459$, $\eta_p^2 = .046$. This suggests that the context switch at test affected younger adults' predictive judgments, but did not affect the older adults.

We hypothesized that younger adults in the PDTD condition would show a context-specificity effect, but younger adults in the TDTD condition and older adults in both TDTD and PDTD conditions would not show a context-specificity effect. To test these hypotheses, we ran a 2 (Group) x 2 (Context) x 2 (Target Cue) ANOVA for each condition. There were no significant main effects or interactions in the TDTD condition (see Table 6), showing that neither group displayed the context-specificity effect in the TDTD condition. In the PDTD condition, there was a significant two-way interaction of Group x Context, $F(1,27) = 15.27$, $\eta_p^2 = .361$. (See Table 7 for all main and interaction effects.) Isolating group, there was a significant main effect of context for younger adults, $F(1,12) = 16.736$, $\eta_p^2 = .582$, but not for older adults, $F(1,15) = .964$, $\eta_p^2 = .342$. Thus, younger adults displayed a context-specificity effect in the PDTD condition, but the older adults did not.

Figure 5. Mean Predictive Judgments of Condition TDTD at Test

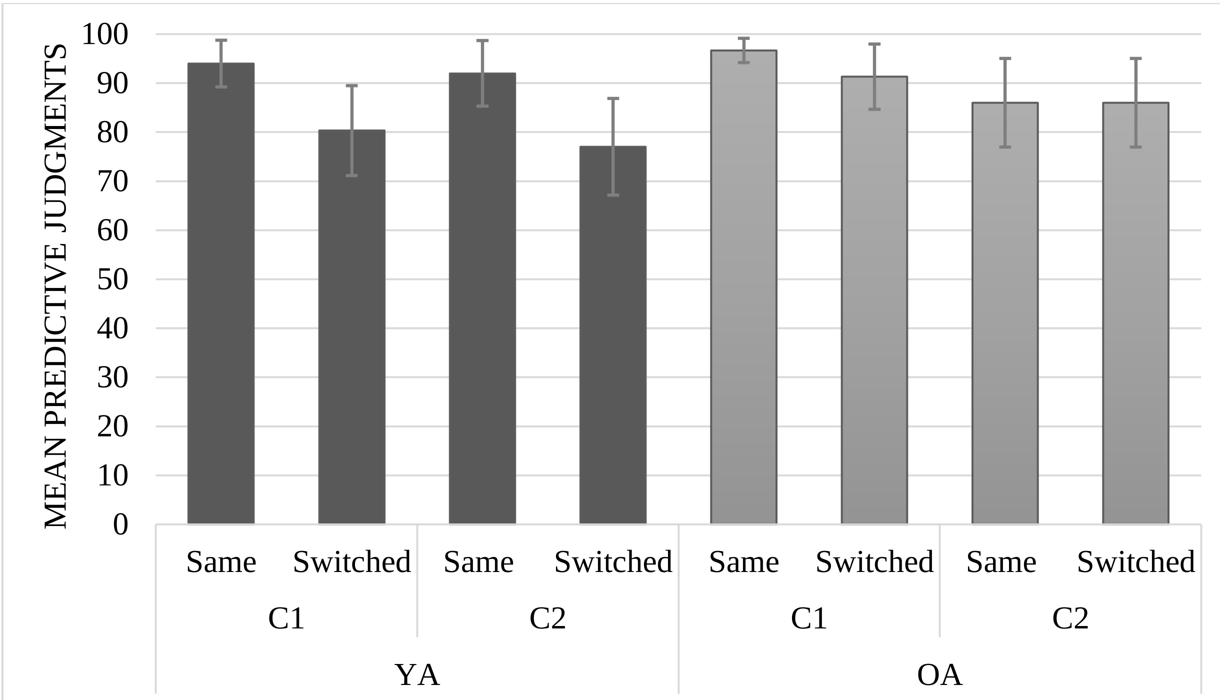


Figure 6. Mean Predictive Judgments of Condition PDTD at Test

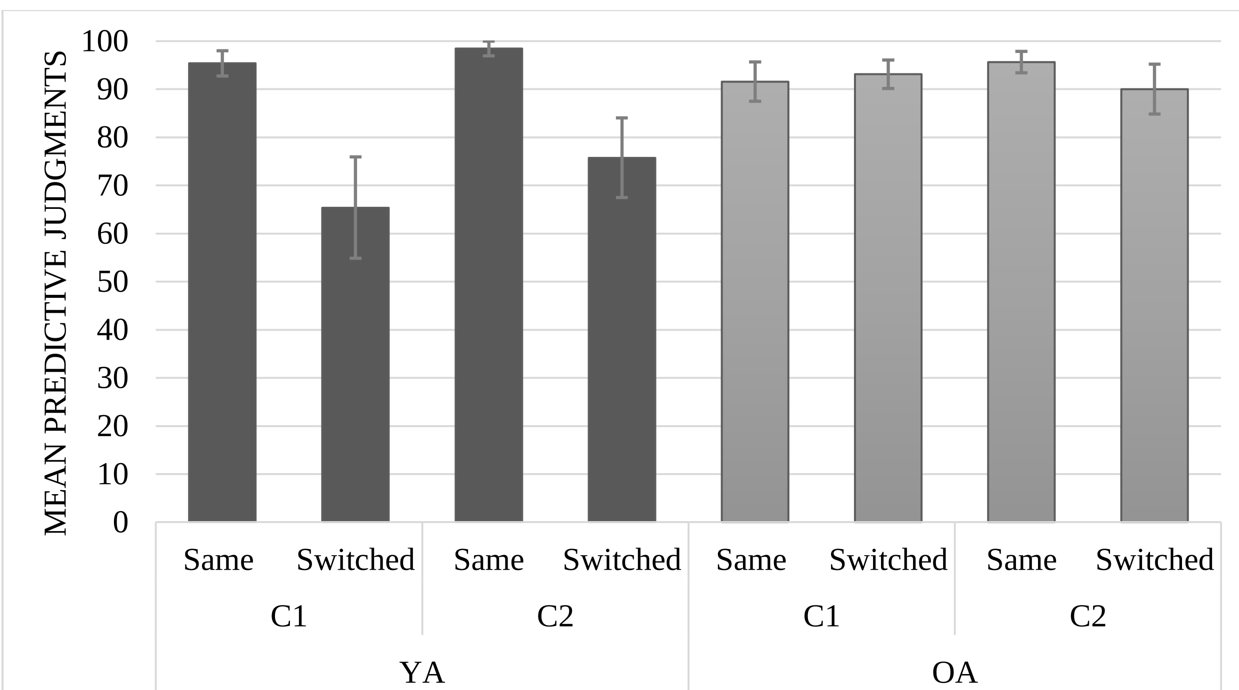


Table 3. ANOVA Table for Learning Phase Compound Cues

Effect	***df***	***MS***	***F***	***p***	η_p^2
Context	1	659.824	1.668	.202	.029
Context X Group	1	259.942	.657	.421	.012
Context X Group X Condition	1	6.674	.017	.897	.00
Error (Context)	55	395.55			
Compound*	1	145885.521	245.589	.00	.817
Compound X Group*	1	7858.221	13.229	.001	.194
Compound X Condition*	1	30851.36	51.938	.00	.486
Compound X Group X Condition	1	510.834	.86	.358	.015
Error (Compound)	55	594			
Block	1	851.557	3.447	.069	.059
Block X Group	1	.851	.003	.953	.00
Block X Condition	1	424.63	1.719	.195	.03
Block X Group X Condition	1	89.449	.362	.55	.007
Error (Block)	55	247.053			
Context X Compound*	1	10615.961	17.297	.00	.239
Context X Compound X Group*	1	5179.806	8.44	.005	.133
Context X Compound X Condition*	1	20337.33	33.202	.00	.376
Context X Compound X Group X Condition*	1	2810.675	4.58	.037	.077
Error (Context X Compound)	55	613.742			

Context X Block	1	357.026	1.165	.285	.021
Context X Block X Group	1	92.992	.303	.584	.005
Context X Block X Condition	1	653.264	2.131	.15	.037
Context X Block X Group X Condition	1	90.963	.297	.588	.005
Error (Context X Block)	55	306.573			
Compound X Block*	1	44537.137	111.499	.00	.67
Compound X Block X Group	1	1347.664	3.374	.072	.058
Compound X Block X Condition*	1	12465.585	31.208	.00	.362
Compound X Block X Group X Condition	1	288.847	.723	.399	.013
Error (Compound X Block)	55	399.438			
Context X Compound X Block*	1	3734.909	14.035	.00	.203
Context X Compound X Block X Group	1	27.341	.103	.75	.002
Context X Compound X Block X Condition	1	262.713	.987	.325	.018
Context X Compound X Block X Group X Condition	1	149.431	.562	.457	.01
Error (Context X Compound X Block)	55	266.119			
Group	1	464.653	.904	.346	.016
Condition	1	486.608	.946	.335	.017

Group X Condition	1	599.728	1.166	.285	.021
Error	55	514.142			

Table 4. ANOVA Table for Learning Phase Single Cues

Effect	***df***	***MS***	***F***	***p***	η_p^2
Context	1	38.069	.306	.583	.006
Context X Group	1	56.504	.454	.503	.008
Context X Condition	1	56.61	.455	.503	.008
Context X Group X Condition	1	51.113	.411	.524	.007
Error (Context)	55	124.547			
Cue*	1	414068.195	1035.702	.00	.95
Cue X Group*	1	5824.271	14.568	.00	.209
Cue X Condition	1	1229.577	3.076	.085	.053
Cue X Group X Condition	1	184.542	.462	.5	.008
Error (Cue)	55	399.795			
Block	1	371.29	2.036	.159	.036
Block X Group	1	190.155	1.043	.312	.019
Block X Condition	1	408.883	2.242	.14	.039
Block X Group X Condition	1	36.821	.202	.655	.004
Error (Block)	55	182.358			
Context X Cue	1	177.074	1.099	.299	.02
Context X Cue X Group*	1	922.861	5.729	.02	.094

Context X Cue X Condition	1	4.152	.026	.873	.00
Context X Cue X Group X Condition	1	232.858	1.446	.234	.026
Error (Context X Cue)	1	161.09			
Context X Block	1	269.455	1.467	.231	.026
Context X Block X Group	1	47.29	.257	.614	.005
Context X Block X Condition	1	61.468	.335	.565	.006
Context X Block X Group X Condition	1	34.081	.349	.557	.006
Error (Context X Block)	55	183.687			
Cue X Block*	1	121076.332	426.822	.00	.886
Cue X Block X Group*	1	2933.872	10.343	.002	.158
Cue X Block X Group X Condition	1	22.448	.079	.78	.002
Error (Cue X Block)	55	283.669			
Context X Cue X Block	1	6.331	.056	.813	.001
Context X Cue X Block X Group	1	333.108	2.967	.091	.051
Context X Cue X Block X Condition	1	22.136	.197	.659	.004
Context X Cue X Block X Group X Condition	1	16.281	.145	.705	.003
Error (Context X Cue X Block)	55	112.285			
Group	1	6.186E – 5	.00	1.0	.00
Condition	1	107.731	.592	.445	.011
Group X Condition*	1	782.513	4.299	.043	.073
Error	55	182.002			

Table 5. ANOVA Table for Test: Omnibus

Effect	***df***	***MS***	***F***	***p***	η_p^2
Context*	1	7549.259	16.166	.000	.227
Context X Group*	1	4746.629	10.164	.002	.156
Context X Condition	1	474.582	1.016	.318	.018
Context X Group X Condition	1	586.523	1.256	.267	.022
Error (Context)	55	466.993			
Cue	1	44.073	.090	.765	.002
Cue X Group	1	492.939	1.010	.319	.018
Cue X Condition	1	1170.277	2.397	.127	.042
Cue X Group X Condition	1	3.162	.006	.936	.00
Error (Cue)	55	488.243			
Context X Cue	1	15.560	.037	.849	.001
Context X Cue X Group	1	56.173	.132	.718	.002
Context X Cue X Condition	1	13.797	.032	.858	.001
Context X Cue X Group X Condition	1	410.462	.965	.330	.017
Error (Context X Cue)	55	425.345			
Group	1	2476.416	2.107	.152	.037
Condition	1	3.590	.003	.956	.00
Group X Condition	1	318.661	.271	.605	.005
Error	55	1175.258			

Table 6. ANOVA Table for Test: Condition TDTD

Effect	***df***	***MS***	***F***	***p***	η_p^2
Context	1	2167.5	3.337	.078	.106
Context X Group	1	1020.833	1.572	.22	.053
Error (Context)	28	649.524			
Cue	1	853.333	1.566	.221	.053
Cue X Group	1	213.333	.391	.537	.014
Error (Cue)	28	544.94			
Context X Cue	1	30	.057	.814	.002
Context X Cue X Group	1	83.333	.157	.695	.006
Error (Context X Cue)	28	530.774			
Group	1	520.833	.298	.59	.011
Error	28	1749.405			

Table 7. ANOVA Table for Test: Condition PDTD

Effect	***df***	***MS***	***F***	***p***	η_p^2
Context*	1	5775.78	20.799	.00	.435
Context X Group*	1	4240.435	15.27	.001	.361
Error (Context)	27	277.701			
Cue	1	371.768	.866	.36	.031
Cue X Group	1	281.251	.655	.425	.024
Error (Cue)	27	429.446			
Context X Cue	1	.026	.00	.993	.00
Context X Cue X Group	1	376.75	1.192	.285	.042
Error (Context X Cue)	27	316.011			
Group	1	2235.951	3.856	.060	.125
Error	27	579.847			

Chapter 4

Discussion

In this study we investigated the difference between younger and older adults in context-specificity effects in learning. We used an ambiguous predictive learning paradigm (Callejas-Aguilera and Rosas, 2010) to encourage participants to attend to context during learning and to produce a context-specificity effect for the learned information during testing. Food-illness associations were learned in one of two restaurant contexts. In the TDTD condition, there was no ambiguity in either context because all food cues were continuously reinforced; i.e., the cues either consistently led to the presence of the illness, or consistently led to the absence of the illness. In the PDTD condition, ambiguity was induced in one context because compound food cues were partially reinforced; i.e., these cues led to presence of the illness equally as often as the absence. The single food cues of each context were continuously reinforced and later served as the test target food cues. During the test, participants made predictive judgments about the probability of target food cues leading to the presence of the illness in the same restaurant context as learned and in the other context. The context-specificity effect occurred when participants made higher predictive judgments for the target food cues when they were presented in the same context as learned than when they were presented in the different context. We hypothesized that ambiguity in the learning phase would encourage young adults to pay attention to context and that they would therefore display a context-specificity effect in the PDTD condition, but not in the TDTD condition. However, we expected that older adults would fail to display a context-specificity effect in either condition due to an inability to bind context to the cue-outcome associations.

Results Summary and Implications

Pre-existing assumptions of food-illness associations were collected in the pre-test. The results of the pre-test ratings indicated that younger adults tended to rate meats and seafoods higher than fruits and vegetables and older adults tended to rate meats, seafoods, and green vegetables higher than fruits. The counter-balancing of the food cues eliminated any potential problems of these biases interfering with the learning phase. Most importantly, biases for the target food cues, C1 and C2, did not significantly differ between the two age groups.

In the learning phase, compound food cues and single food cues were analyzed separately because manipulations of compound food cues induced ambiguity and single food cues were used as test target food cues. Continuously reinforced compound food cues in TD blocks were accurately discriminated by both age groups as shown by the analysis of the significant four-way interaction of Group x Condition x Context x Compound. This interaction also revealed that older and younger adult participants remained unsure of the probability of the partially reinforced compound food cues in the PD blocks. However, the Condition x Compound x Block interaction revealed that though participants in the PDTD condition discriminated the continuously reinforced compound cues, this discrimination was worse than that of participants in the TDTD condition for both age groups. Additionally, this effect was worse for older adults than for younger adults. This suggests that, for the older adults, the presence of ambiguity in the learning phase led to some confusion about the expected outcome for continuously reinforced compound cues. Not surprisingly given our learning criteria, all participants discriminated the single food-illness associations by the final learning block of each context. This discrimination was essential to conclude that lower predictive judgments of target food cues in the test was due to the context-specificity effect and not a lack of acquiring the accurate discrimination.

The predictive judgments for the target food cues in the test supported both of our hypotheses. In support of our first hypothesis, younger adults did not display a context-specificity effect in the TDTD condition, but did display a context-specificity effect in the PDTD condition. Though there was a decrease in test mean predictive judgments of target food cues in different contexts in both the TDTD and PDTD conditions, this effect was not significant in the TDTD condition. In contrast, in the PDTD condition, test predictive judgments were significantly lower when the target food cue was presented in the different context than learned than when the target food cue was presented in the same context as learned. This suggests that the ambiguity of the learning phase encouraged younger adults in the PDTD condition to pay attention to the context. In accordance with the attentional theory of context processing (Rosas, Callejas-Aguilera et al., 2006), they bound context to the food-illness associations, causing these associations to become context-specific. This led younger adults in the PDTD condition to make lower predictive judgments for the target food cues when they were presented in a different context than originally learned. The younger adult participants had equal exposure to both contexts, so these results cannot be attributed to novelty of the different context. Therefore, the observed context-specificity effect in the PDTD condition can be attributed to ambiguity.

Younger adults' predictive judgments in the test displayed the context-specificity effect for target food cues from both the PD (C1) and TD (C2) blocks. Ambiguity was induced through partial reinforcement of compound cues, but all target food cues were continuously reinforced. There was no indication from the learning phase for the probability of the target food cues leading to the illness to decrease when the context switched. Therefore, the ambiguity of the PD blocks led younger adult participants to bind context with the food-illness associations in both the ambiguous PD blocks and the non-ambiguous TD blocks. This observation supports other studies (Rosas, Garcia-Gutierrez et al., 2006; Rosas & Callejas-Aguilera, 2006) which suggested the general presence of ambiguity in the learning phase led participants to bind all information to the co-presented context, and thus, display the context-specificity effect at the test.

In support of our second hypothesis, older adults did not display a context-specificity effect in either condition. Given prior research (Callejas-Aguilera & Rosas, 2010; Hogarth et al., 2008; Nelson et al., 2013; Rosas, Callejas-Aguilera, et al., 2006), there was no expectation of a context-specificity effect from the TDTD condition in either group because there was no ambiguity to cause participants to pay attention to the context during the learning phase. However, unlike younger adults, older adults did not display a context-specificity effect in the PDTD condition. Regardless of the condition, older adult participants' predictive judgments of the target food cues did not significantly differ whether the food was presented in the same or difference context as learned. This suggests that older adults did not bind the context to the food-illness associations even when the meaning of the associations was ambiguous.

Interestingly, because older adults did not display a context-specificity effect, their predictive judgments for the target cues were more accurate than those of younger adults in the PDTD condition. Younger adults, especially in the PDTD condition, decreased their predictive judgments of the food-illness associations when the context switched. Older adults continued to rate each target food cue the same in spite of the context that was co-presented. Therefore, younger adults displayed the desired context-specificity effect, but older adults displayed greater performance on the task. This finding is rare in the aging literature where younger adults routinely outperform older adults (Jones et al., 2016; Kessels et al., 2007; Mutter & Plumlee, 2009, 2014; Peterson & Naveh-Benjamin, 2016).

These results both replicate and extend the current literature on the context-specificity effect in associative learning. Our results for younger adults replicate those from Callejas-Aguilera and Rosas' (2010) Experiment 1 investigating the role of ambiguity in the context dependency of information. Their results showed no context-specificity effect in the TDTD condition, but a significant context-specificity effect in the PDTD condition. This lends greater support for the role of ambiguity in the attentional theory of context processing (Rosas, Callejas-Aguilera, et al., 2006). However, the absence of the context-specificity effect in the older adult group suggests the necessity of an amendment to this theory. The presence of ambiguity encouraged younger adults to attend to and encode context information. Older adults, however, did not use contextual information to modulate predictive judgments, implying that the presence of ambiguity did not lead older adults to attend to and encode context. This suggests that the role of ambiguity in the attentional theory of context processing is limited to younger adults.

Our results extend the current literature in support of the associative deficit in aging to suggest that older adults do not associate information to context, even in conditions that younger adults consistently display a context-specificity effect. The lack of the observed context-specificity effect extends and replicates the animal research on context-specificity in predictive learning to humans (Wiescholleck et al., 2014). The associative deficit does not imply an inability to bind all cue-outcome associations: older adults of the current study successfully learned to discriminate the single food-illness associations. However, the binding of multiple cues to an outcome is a commonly observed deficit in older adults (Kessels et al., 2007). In order to bind a cue-outcome association to the context, the individual must attend to the context and form an additional association with cue and context (Rosas, Callejas-Aguilera et al., 2006). The context then acts as an occasion setter (Holland, 1992) to modulate the expected outcome for the cue. Therefore, the association of cue and context must be made before context can act as an occasion setter. The lack of the context-specificity effect in a learning paradigm suggests older adults' item-context binding deficit (Peterson & Naveh-Benjamin, 2016) led to an inability to form the association of cue and context in addition to the primary cue-outcome association. This then resulted in the observed failure of older adults to use the occasion setting property of contextual cues to inform responses in both memory (Jones et al., 2016) and learning, as shown by the current study.

In addition to exhibiting an item-context binding deficit, the older adults struggled to bind the multiple foods of compound cues with the outcome in the PDTD condition. Discrimination by the last learning block was significant, but this discrimination was not as strong as the younger adults' (in accordance with Mutter & Plumlee, 2014). Even with five learning blocks, a total of 20 trials per each single food cue and compound food cue, the older adults in the PDTD condition struggled to discriminate the compound food-illness associations of context B (WH+, WR-) despite the continuous reinforcement of these cues. However, older adults in the TDTD condition were able to discriminate the compound food-illness associations just as well as younger adults. This suggests the ambiguity of the PD blocks disrupted the discrimination learning of the TD blocks for older adults in the PDTD condition. Thus, ambiguity did affect discrimination learning, but the older adults did not use context to help disambiguate the cues. If the older adults of PDTD had used context, their discrimination for the continuously reinforced compound cues of context B would have been similar to the younger adult performance. This suggests the presence of ambiguity did not lead to the same steps of context processing for the older adults as it did for the younger adults.in the PDTD condition.

Limitations and Future Directions

One limitation of the current study was the different number of learning blocks between groups. The older adult group took longer to learn the food-illness discriminations of the single food cues, but they also had more exposure to these cues. A couple of studies suggest that increasing learning trials decreases the observed context-specificity effect in younger adults (Leon et al, 2010; 2011). In tasks with partial reinforcement, increasing the number of trials might signal to the participant that the context is not informative of the cue's outcome. If this occurred in our study, then the older adult's predictive judgments at test could have been due to an increase in the number of trials instead of to an inability to bind context. However, this would imply that older adults reached a learning asymptote and ceased to attend to context because it lacked further informative value. If only older adults reached this learning asymptote, then their discriminations of food-illness associations should have been greater than younger adults, yet the graphs of the learning data do not support this assertion. Neither the graphs, nor statistical analyses support a claim that older adults acquired better discriminations than younger adults by the last learning block. A future study could use a software that tracks participant progress and discontinues the learning phase after a participant's predictive judgments discriminate the food-illness associations for a complete learning block. This might offer enhanced control for individual differences in learning.

Another limitation was the number of stimuli in a single learning trial. This was of particular concern in the older adult group who generally struggle with binding multiple cues to an outcome (Kessels et al., 2007). Older adults in the PDTD condition learned the compound cues more slowly than older adults in the TDTD condition and younger adults. The presence of ambiguity decreased discrimination of compound cues in the PDTD condition, but the lack of the context-specificity effect could have occurred because of the high cognitive load of stimulus competition coupled with ambiguity. If the ambiguous compound cues were not bound to context, then the continuously reinforced target cues should not bind to context. Also, a few older adults attempted to link the food-illness associations with the random names presented in the inter-trial stimulus screen. This is of particular interest because it suggests that older adults did attempt to bind the food-illness associations with external stimuli, but there was still no context-specificity effect. Simplifying this task by inducing ambiguity in single cues could allow stronger manipulations in future studies on aging.

Finally, the current results do not differentiate between item-context binding (Peterson & Naveh-Benjamin, 2016) and item-context retrieval (Braver et al., 2001) in the context-specificity effect. For the younger adults in the PDTD condition, the observed context-specificity effect suggests that the food-illness association was bound to context and this association was retrieved during the test, affecting predictive judgments when the target food cue was presented in a different context. The absence of a context-specificity effect in the older adult PDTD condition does not provide any insight into the type of deficit they experience in context processing. The learning phase results of the compound cues suggests that older adults did respond to ambiguity, but failed to use context to disambiguate the outcomes. It is unclear whether this failure to use context was due to a lack of attention to context or a cognitive inability to bind or retrieve context. The predictive learning task did not isolate participants' ability to attend, encode, or retrieve context (Braver et al., 2001). It is possible that the older adult participants succeeded in initial item-context binding, but failed to retrieve the association or apply it in the test. Future studies should continue to investigate context processing in the aging population by separating contextual encoding and retrieval.

Conclusions

In conclusion, our hypotheses were supported in that a context-specificity effect was observed in the younger adult PDTD condition, but was not observed in the younger adult TDTD condition or either older adult condition. The presence of ambiguity in the learning phase did lead younger adults to attend to context. This produced a context-specificity effect in the test for target food cues in the same context as learned and in the different context. Despite the presence of ambiguity in the learning phase, older adults failed to use the contextual information. Thus, a context switch during the test did not influence older adult predictive judgments for the food-illness associations. These results have implications for the attentional theory of context processing (Callejas-Aguilera & Rosas, 2010) and for the associate deficit in aging.

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Appendix

Appendix 1. Predictive Learning Experimental Task Instructions

"Recent developments in food technology led to the chemical synthesis of food. This creates a great advantage as its cost is very low, and it is easy to store and transport. This revolution in the food industry may solve hunger in third world countries.

"However, it has been detected that some foods produce gastric problems in some people. For this reason, we are interested in selecting a group of experts to identify the foods that lead to some type of illness, and how it appears in each case.

"You are about to receive a selection test where you will be looking at the files of persons who have ingested different foods in a specific restaurant. You will have to indicate in which degree you think that a gastric problem will appear. To respond you should click the option that you consider appropriate. Make sure to choose carefully as only your first choice will be recorded. Your response will be random at the beginning, but do not worry, little by little you will become an expert.

"Do you have any questions? The experimenter will now demonstrate your task in a practice trial."