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Review

How age and culture influence cognition: A lifespan developmental perspective

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ABSTRACT

It has long been assumed that cognitive aging is a universal phenomenon. However, increasing evidence substantiates the importance of individual differences in cognitive aging. How do experiential factors related to culture shape developmental trajectories of cognition? We propose a new model examining how age and culture influence cognitive processes, building on past models and expanding upon them to incorporate a lifespan developmental perspective. The current model posits that how age and culture interact to influence cognition depends on (a) the extent to which the cognitive task relies on top-down or bottom-up processes, and (b) for more top-down processes, the level of cognitive resources required to perform the task. To assess the validity of the model, we review literature not only from adulthood but also childhood, making this the first model to adopt a lifespan perspective in the study of culture and cognition. The current work advances understanding of cognitive aging by delineating the combined effects of biological aging processes, assumed to apply across cultures, and culture-dependent experiential aging processes, which reflect unique cultural experiences throughout one's lifespan. This approach enables understanding of comprehensive potential mechanisms that underlie the influence of culture on cognitive development across life stages.

Introduction

It has long been appreciated that various cognitive abilities, including attention (Cona, Bisiacchi, Amodio, & Schiff, 2013; McDowd & Filion, 1992), memory (Hasher & Zacks, 1988; McDowd & Shaw, 2000; Reuter-Lorenz & Sylvester, 2005), processing speed (Finkel, Reynolds, McArdle, & Pedersen, 2007; Salthouse, 1996), and inhibitory control (Dempster, 1992; Hasher & Zacks, 1988; Kramer, Humphrey, Larish, & Logan, 1994), decline with age. Many of these declines are assumed to reflect age-related biological or

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neurophysiological changes,[1] such that cognitive aging inevitably and universally reduces individuals' cognitive functioning (e.g., Gutchess, 2019; Salthouse, 2012; Thomas & Gutchess, 2020). Increasing evidence, however, also suggests the important role of experiential factors (e.g., early experiences, lifestyle) in cognitive aging, which challenges the idea of universal decline with age. For example, isolated older adults during the COVID-19 pandemic are more likely to have greater risk of cognitive impairment compared to the non-isolated counterparts (Noguchi et al., 2021) and men who experienced early life stress (e.g., separation from their parents) showed greater cognitive declines later in life compared to their counterparts without early life stress (Pesonen et al., 2013). A *meta*-analytic review illustrated that people with higher levels of physical activity are less likely to have risk of dementia and cognitive declines (Blondell, Hammersley-Mather, & Veerman, 2014). The recent emphasis on training interventions (e.g., Hertzog et al., 2008; Kivipelto et al., 2020), by using multidomain interventions including physical exercise, cognitive engagement, and dietary counseling, also underscores the potential to remediate cognition with age. These findings illustrate the importance of investigating how experiential factors relate to different trajectories of cognition with age, namely, individual differences in cognitive aging.

Despite some earlier calls to consider culture in cognitive aging (Park, Nisbett, & Hedden, 1999; Park & Gutchess, 2006) there has only recently been more widespread integration of culture into the empirical study of cognitive aging. In this paper, we will explore how culture, conceptualized as an individual difference factor based on life experiences, influences cognitive processes jointly with age. We will do so by reviewing existing models to account for the joint influences of culture and aging, and propose a revision to these models. Then we will review literature to assess the model, incorporating not only findings from the adult development literature but expanding the scope to include child development. This manuscript is the first to adopt a lifespan perspective in considering the effects of culture on cognitive development.

Culture is a broad term referring to the experiences, values, beliefs, customs, attitudes, and perspectives that are shared by a group of people. A group could be defined based on geography (e.g., country, regions), demographics (e.g., ethnicity), or affiliations (e.g., occupation, social group). Because of such a broad and abstract construct, there is not a consensus on how to define culture in the scientific literature. In this paper, we define culture based on geography (i.e., country or global region, such as the comparison of East vs. West) because this is one of the common ways of defining culture in the field of psychology. We acknowledge the ways in which this dichotomy is an oversimplification (e.g., Gutchess & Rajaram, 2023; Kitayama & Salvador, 2024; Vignoles et al., 2016) and does not account for the diversity of cultures across the globe (Kitayama & Salvador, 2024) or potential variation within a country (Talhelm et al., 2014; Talhelm & Dong, 2024). Nevertheless, this framework for conceptualizing culture serves as a starting point.

Two theories dominate the cross-cultural literature, generally with a focus on East-West comparisons (i.e., Asia, especially East Asia, vs. North America, Western Europe, and Australia) (see Grossmann & Na, 2014 for review): (a) interdependent vs. independent self and (b) holistic vs. analytic thinking styles. Individuals from the East are likely to hold interdependent views of the self, which emphasize social norms and harmony, and to have holistic thinking styles, prioritizing processing information as a whole and attending to context and the relationships amongst parts. In contrast, individuals from the West are likely to hold independent views of the self, which emphasize autonomy, and to have analytic thinking styles, which focus on object and parts, and show a preference for using logic and rules (Markus & Kitayama, 1991; Nisbett & Miyamoto, 2005; Nisbett, Peng, Choi, & Norenzayan, 2001).

These cultural differences in self-concept and thinking styles affect cognitive processing (see Wang, 2018). Although culture has scarcely been studied in the field of cognitive psychology – most of the culture-related papers related to cognition focus squarely on language or bilingualism (see Gutchess & Rajaram, 2023) – evidence is mounting to suggest that culture can influence cognitive processes, including attention (Alotaibi, Underwood, & Smith, 2017; Amer, Ngo, & Hasher, 2017; Boduroglu, Shah, & Nisbett, 2009; Chua, Boland, & Nisbett, 2005; Masuda & Nisbett, 2006), memory (Leger, Cowell, & Gutchess, 2023; Wang, 2001, 2009; Wang & Conway, 2004; *see* Wang (2021) for a review), perception (Blais, Jack, Scheepers, Fiset, & Caldara, 2008), strategies for information processing (Norenzayan, Smith, Kim, & Nisbett, 2002; Unsworth, Sears, & Pexman, 2005), and social cognition (Masuda et al., 2008; Park, Vepachedu, Keshava, & Minns, 2022). For instance, East Asians, thought to have holistic perspectives, more easily detected color changes when the display view expanded whereas Americans, thought to have focal object-centered views, more easily detected color changes when the display view shrunk (Boduroglu, Shah, & Nisbett, 2009). Compared to East Asians, European Americans have a tendency to report more specific episodes when being asked to recall the past (Wang, 2001) and to have more accurate memory for the perceptual details of objects (Millar, Serbun, Vadalia, & Gutchess, 2013). In addition, European Americans are likely to encode object information regardless of contexts whereas East Asians are likely to encode objects with their surrounding contexts (Masuda & Nisbett, 2001). In terms of reasoning styles, European Americans tend to use rule-based strategies (e.g., using a unidimensional rule when evaluating the similarity between a new stimuli and other exemplars), whereas Asians tend to use experience- or instance- based ones (e.g., using an overall resemblance criterion when evaluating the similarity between a new stimuli and other exemplars) (Norenzayan et al., 2002). Cultural differences in information processing also can be observed in social cognition, such that when judging the emotion of a central person flanked by others, East Asians are more influenced by the emotions displayed by the surrounding people compared to Americans (Masuda et al., 2008). These cross-cultural comparisons of cognitive processing mentioned above are based on

[1] Although biological aging refers to the age-related changes in biological or physiological systems (e.g., cells, tissues, organismal function) (Hamczyk et al., 2020), the term "(neuro)biological aging" in this manuscript more refers to the cognitive changes in organisms with age that may be due to biological or physiological factors (e.g., the declines in memory in older adults due to hippocampal atrophy, the deterioration of executive functioning in older adults owing to the structural changes in prefrontal cortex), thereby general age-related changes commonly observed across individuals regardless of environmental and experiential factors (e.g., culture). We acknowledge that biological aspects can be modifiable due to experience (e.g., Boyke et al., 2008), but perhaps that only slows down cognitive aging (e.g., Dahlin et al., 2008). Therefore, this term is used in the current paper as a concept to contrast environmental from experiential factors.

the study of younger adults. What types of cultural differences emerge for older adults? How do cultural differences affect cognitive aging?

Why is considering culture important to our understanding of cognitive Aging?

Some might wonder why it matters to take culture into account in understanding cognitive aging. Considering culture can allow us to better understand the trajectories of cognitive aging. First, it can expand our understanding of cognitive aging by questioning the generalizability of previous findings. Given that previous literature on cognition (and cognitive aging) predominantly draws on WEIRD (Western, Educated, Industrialized, Rich, and Democratic) samples (Henrich et al., 2010), it is possible our current understanding of cognitive aging is constrained by existing samples. By considering culture and including diverse cultural groups as research samples, we can scrutinize whether the previous findings in the cognitive aging literature are observed in other cultural groups. If the patterns of findings do replicate across cultural groups, that would indicate that the patterns identified in the current predominantly Western literature on cognitive aging are universal. If the findings do not extend across cultural groups, that indicates that the patterns of cognitive aging are culturally-bound, perhaps limited to WEIRD samples.

Examining the joint effects of culture and aging on cognition also allows for the comparison of the effects of experiential, lifestyle factors (e.g., culture) and neurobiological factors (e.g., structural and functional brain changes; see Murman, 2015 for review) on cognitive changes with age (Park & Gutchess, 2006). For example, if we find similar patterns in cognitive processes across cultures, we can have relatively more confidence that such processes depend on biological aging, whereas if we find varied patterns depending on culture, we can infer that the processes depend on experiential factors, indicating plasticity in cognitive processes with age (Park & Gutchess, 2006). In other words, we can explore the extent to which cognitive processes can vary depending on cultural experiences as well as due to age-related biological factors that may operate as universals, eradicating the effects of culture on cognition present at earlier stages of development. As briefly discussed in the previous section, cultural differences in memory can occur for younger adults (i.e., more detailed recall of objects or episodes in European Americans, compared to East Asians). However, if the integrity of the hippocampus is critical for supporting cultural differences in memory, changes due to aging and pathology (e.g., Alzheimer's disease), such as loss of neurons in the hippocampus, reduced hippocampal volume, or changes in connectivity between the hippocampus and other brain regions (see Bettio et al., 2017 for review), then cultural differences might not be observed for older adults.

More importantly, investigating the patterns of cognitive aging with consideration of culture can be beneficial to uncover factors that modulate cognitive aging. For example, identifying protective factors or strategies that tend to naturally occur in one cultural context could inform the design of effective interventions that could be applied more widely. Studying diverse cultural samples could have the benefit of discovering potential interventions to reduce the effects of cognitive aging or to design culturally-appropriate interventions (see Barber et al., in press for further discussion). Such promising interventions may have not yet been identified due to the culturally-bound and limited samples studied in the existing literature.

The possibility that cultural and biological factors may have opposing influences begs the question of how culture may interact with cognitive processes with age. On one hand, cultural differences in cognitive processes present in young adults can further diverge with age, reflecting the culture-specific experiences that amass over the lifespan and lead to distinct patterns of performance for different cultures (Park et al., 1999). More specifically, as individuals absorb cultural knowledge and practices over their lifetimes, a specific strategy that is favored by their culture can become more efficient and require fewer cognitive resources to successfully implement. For example, cultural differences in memory strategies found in younger people can be enlarged or at least persist in older adults. On the other hand, cultural differences can diminish with age, as the cultural groups converge due to biological aging processes that prevent the culture-specific strategies from being successfully enacted (Park et al., 1999). Integrating these ideas, the initial model that first outlined joint effects of age and culture on cognitive processes will be discussed in the next section.

Initial model (Park, Nisbett, and Hedden, 1999): Automatic vs. Controlled processes

The Park, Nisbett, and Hedden (1999) model accounting for how age and culture interact to shape cognition conceptualized the influence of culture on cognition by distinguishing between culture-invariant and culture-saturated tasks. For culture-invariant cognitive tasks, tasks that draw on general cognitive resources without employing culture-specific knowledge or strategies (e.g., a spatial working memory task in which no cultural strategies, biases, or knowledge are involved; a task using abstract stimuli), no cross-cultural differences would emerge for younger and older adults. Effects of aging on cognitive performance, however, would be expected across cultures. Therefore, no interaction between age and culture would be predicted for culture-invariant cognitive tasks because performance on these tasks primarily depend on neurobiological aging factors which operate independent of culture. By contrast, culture-saturated cognitive tasks draw on culture-specific knowledge, strategies, and biases (e.g., digit/letter working memory test in which participants may use culturally different strategies reflecting differences in language and numeracy), so cross-cultural differences in performance would be expected. Such effects of culture would be predicted to interact with age, but importantly, the model suggests that the nature of the interaction between age and culture depends on whether a task relies on automatic or controlled processes.

The distinction between automatic and controlled processes depends on whether a task requires cognitive resources or not (Schneider & Chein, 2003). For instance, controlled processes are slow and effortful, requiring control and attention to process, but flexible, whereas automatic processes are effortless, fast, but less flexible in how they respond to external and environmental factors. If a task is based on more automatic processes (e.g., using an implicit categorization strategy for memory, self-referencing memory; that would not demand high cognitive resources, thereby being less impacted by neurobiological aging effects), the model predicts that cultural effects would amplify with age. This is because cultural knowledge, practice and experiences accumulate over time, including over the adult lifespan, and tasks relying on automatic processes are less impacted by age-related declines in cognitive resources (Park et al., 1999). In contrast, if a cognitive task relies on more controlled processes (e.g., speed of processing, working memory, inhibition), the performance of cultural groups would be expected to converge with age. Specifically, older adults, presumed to have lower levels of cognitive resources compared to younger adults due to neurobiological aging, would be expected to have limited resources available to support cognitive flexibility, such as adopting a less practiced strategy for their culture. Thus, no cultural differences, or reduced cultural differences, would be predicted for older compared to younger adults. Age-related declines in performance, however, would be expected across cultures for tasks relying on controlled processes. The predicted patterns for automatic and controlled processes are depicted in Fig. 1.

In testing this model, Park et al. (1999) emphasize the importance of ensuring that samples are equated across culture on cognitive resources. Matching samples is critical to avoid confounds resulting from the comparison of mismatched groups (e.g., inadvertently drawing from a high-functioning sample in one culture and a lower-functioning sample in another culture, and attributing differences in task performance to culture). This is particularly important for comparisons of older adults. Samples of younger adults are typically drawn from college populations, which can support some similarity in educational attainment and experience. For older adults, however, high variability can occur due to potential differences in educational opportunities, lifetime experiences with different enrichment activities and occupational complexity, and effects of cognitive aging and age-related pathology. This necessitates establishing which neuropsychological measures are culturally-invariant and can be used to measure cognitive abilities across cultures.

To address this question, Hedden et al. (2002) attempted to identify culturally-invariant neuropsychological measures. This also served to test Park et al. (1999)'s model by comparing younger and older American and Chinese adults on speed of processing and working memory measures. Some tasks were visuospatial (i.e., Pattern Comparison task and Corsi Block task – forward & backward); researchers did not expect cultural differences for these, making them culture-invariant tasks. The other type of the task was numeric (i.e., Digit Comparison task and Digit Span task – forward & backward); due to linguistic differences in the pronunciation length of digits between English and Mandarin Chinese, the researchers anticipated cultural differences in performance, making these culture-saturated tasks. Aligning with what Park et al. (1999)'s model proposed, for culture-invariant tasks, there was only an effect of age, but the decline in task performance with age did not interact with culture. In contrast, for the culture-saturated tasks, cultural differences were found for younger adults. How culture and age interact depends on the level of cognitive resources required by a task. For the task requiring lower cognitive demands (i.e., Digit Span task – forward), cultural differences were observed in both younger and older adults. But for the task requiring higher cognitive demands (i.e., Digit Span task – backward), the cultural groups converge with age. Fig. 2 illustrates these different patterns of cultural effects. The findings suggest that the visuospatial tasks could be culturally-fair measures of cognitive abilities, and support the importance of considering cognitive demands and cultural saturation of tasks, in accordance with the Park et al. (1999) model.

Revised model (Gutchess and Gilliam, 2022): Top-down vs. Bottom-up processes

The Park et al. (1999) model provided a systematic and fundamental approach to account for how culture and age jointly affect cognition, and was seminal for identifying how processes should be thought about when considering the joint effects of culture and age. However, this initial model faced limitations in explaining some subsequent data. Specifically, Gutchess and Gilliam (2022) argued that some tasks purported to be automatic in fact interact with cognitive resources. For example, in Gutchess et al. (2006), younger and older American and Chinese adults were tested with a memory task utilizing categorization skills (i.e., recalling words that were categorically related or unrelated). Under Park et al. (1999)'s model, there should not only be cultural difference in performance on the memory task, due to a greater preference and experience using taxonomic categories, a strategy supported by the task, for Americans compared to Chinese. But there also should be a larger cultural difference for older adults due to their well-practiced and automatic use of category structure compared to younger adults. Results demonstrated that Americans, particularly older adults, used

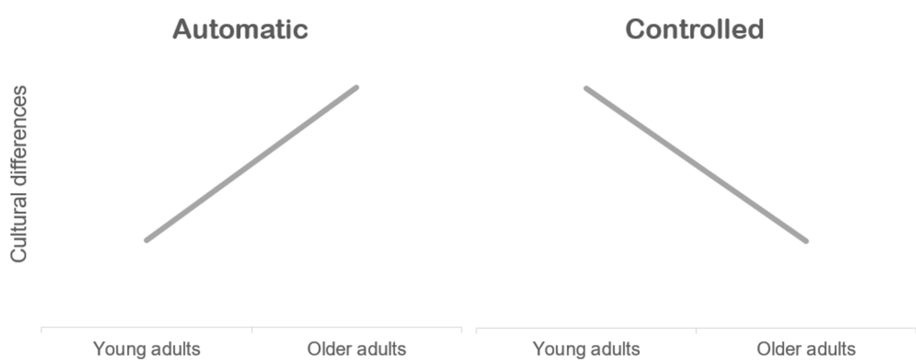

Fig. 1. The Park et al. (1999) model makes different predictions for the trajectory of cultural differences with age in adulthood depending on whether the task draws on automatic or controlled processes.

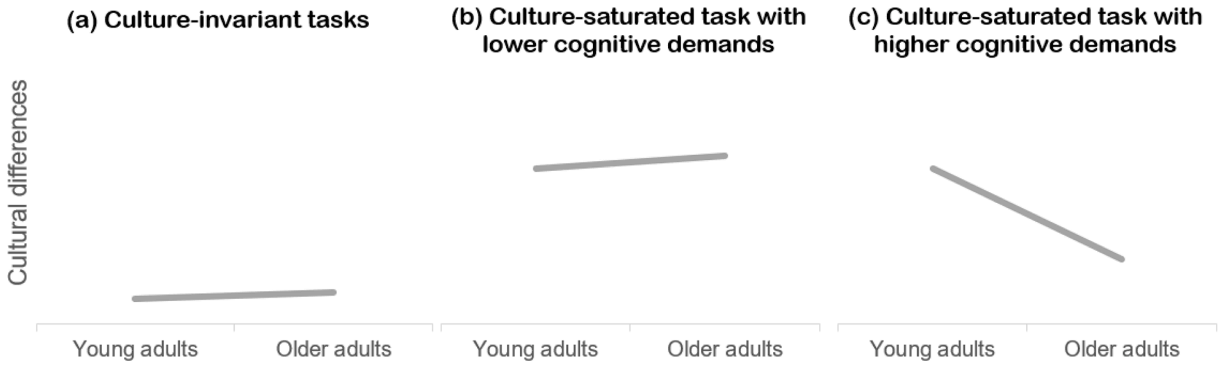

Fig. 2. Summary of results from Hedden et al. (2002), to illustrate the effects of culture for young and older adults for different types of tasks: (a) culture-invariant tasks (i.e., Pattern Comparison task and Corsi Block task – forward & backward), (b) culture-saturated task with lower cognitive demands (i.e., Digit Span – forward), and (c) culture-saturated task with higher cognitive demands (i.e., Digit Span – backward). Please note that the graphs are for illustration, and do not reflect actual data points.

categorization in their recall more often than their Chinese counterparts, but unexpectedly, the cultural difference in the use of categories did not extend to memory performance. That is, the cultural groups did not differ in the number of words recalled. Furthermore, older adults, regardless of culture, categorized less and recalled fewer words than their young counterparts, showing an interaction between categorization skills, suggested to be automatic and independent of cognitive resources under Park et al. (1999)'s model, and cognitive resources that are reduced with age.

Another example from Gutchess and Gilliam (2002) involves visual object-processing, studied in younger and older adults from the U.S. and Singapore (Chee et al., 2006; Goh et al., 2007). Participants passively viewed visual stimuli (e.g., a combination of an object and a background) during fMRI scans and visual adaptation was assessed by measuring changes in the neural response to different alterations of the stimuli (i.e. in some cases, both object and background were repeated or replaced with novel images, and in the other cases, either the object or background was replaced). Because participants passively viewed images without completing a task that involved controlled processing, it is assumed to be automatic according to Park et al. (1999)'s model. Results showed cultural differences in the visual processing of objects such that less visual adaptation (i.e., less sensitivity to repetition of objects) in lateral occipital complex was found in Singaporeans compared to Americans, but such cultural differences were observed in older adults only (Goh et al., 2007). This pattern indicating enlarged cultural differences with age was consistent with Park et al. (1999)'s model. However, when participants were instructed to attend to objects or when objects were provided without backgrounds, older Singaporeans' adaptation was restored, suggesting sensitivity to objects (Chee et al., 2006). The results imply that the passive visual processing assumed to be automatic processes based on Park et al. (1999)'s model depends on cognitive resource-related factors, such as task instructions and task difficulty.

To address these challenges to the Park et al. (1999) model, Gutchess and Gilliam (2022) proposed a revision. The revised model differs from the Park et al. (1999) at least in two ways. First, instead of focusing on the distinction between automatic and controlled processes, this model used the framework of top-down and bottom-up processes. Top-down vs. bottom-up processes are distinguished based on whether cognitive processes rely more on a lower-level sensory stimulus (bottom-up) or higher-level internal guidance such as prior knowledge, experiences, motivations, goals, and expectations (top-down). Top-down vs. bottom-up processes are different from automatic vs. controlled processes in that the former ones focus on how information is processed (i.e., relying more on the lower-level stimulus properties [bottom-up] or higher-level internal guidance [top-down]), whereas the latter ones consider how much a process necessitates cognitive resources. Therefore, top-down (or bottom-up) processes do not correspond to controlled (or automatic) processes. For instance, there could be bottom-up but controlled processes that require cognitive resources to process but rely more on a lower-level sensory properties (e.g., finding a key in a messy room based on its sensory feature, such as color, size, and shape), and there could be top-down but automatic processes that rely more on higher-level internal guidance but do not require cognitive resources (e.g., daily commute; the prior experience of driving on a familiar route can allow individuals do it without effort or conscious monitoring of the signs and route).

Second, the Park et al. (1999) model assumed none or some cognitive resources are required by a task, whereas the Gutchess and Gilliam (2022)'s model emphasized the continuum of cognitive resource demands. Rather than treating cognitive resource demands as discrete (i.e., controlled vs. automatic), a continuum appears to better reflect the way we perform cognitive tasks and allows for greater flexibility. Cognitive tasks might include a combination of multiple processes (e.g., interaction between top-down and bottom-up processes; Awh, Belopolsky, & Theeuwes, 2012). Even if individuals perform the same cognitive task, which processes are emphasized can differ by conditions (i.e., having different instructions or contexts).

Therefore, this Gutchess and Gilliam (2002) framework distinguishes between bottom-up processes that are driven by the stimulus (e.g., the frequency of light waves striking the retina, inducing the perception of a particular color) from top-down processes that allow a person to fill in and interpret information, informed by their goals, motivations, values, and experience. The extent to which tasks rely on top-down versus bottom-up processes determines the extent to which cultural differences should emerge, and how aging would be expected to affect these patterns. The model acknowledges that all cognitive tasks involve a combination of top-down and bottom-up processes and that the processes exist on a continuum, rather than having a clear transition from level to another.

For tasks profoundly influenced by top-down processes (i.e., motivational and experiential influences), there is greater flexibility in the ability to use strategies or to have subjectively different interpretations of stimuli depending on one's experience. Examples of tasks involving strong top-down influences are self-referencing memory tasks, in which cultural differences in self-construal can impact what is remembered, and categorization memory tasks, in which knowledge of categories is used to organize incoming information. Accumulated experience over a lifetime in a specific culture could exaggerate cultural differences in older, compared to younger adults, or, alternatively, could at least support maintenance of the cultural differences seen in younger adults in older adulthood.

At the intermediate level, there are strong contributions from attentional influences. Although top-down processes are implicated at this level, they face strong constraints due to the availability of attentional resources. Tasks in which individuals must control their attention to focus on particular aspects of a display or for which particular components capture attention more than others can be examples of this intermediate level. For example, emotion-induced trade-off memory effects occur because emotionally-valenced items, such as a gun, capture attention more than neutral items (Kensinger, 2007). In complex scenes, emotional items will be better remembered than neutral ones, but this comes at the expense of memory for the background. Neutral backgrounds are remembered worse when paired with an emotional item than with a neutral item. This emotion trade-off effect has been demonstrated to be larger for Americans than Turks (Gutchess et al., 2018). This cultural difference reflects a combination of bottom-up processes because attentional capacity limitations necessitate trade-offs in what information is attended to and processed to form memories, and top-down processes; because Turks value contextual information more than Americans, they do not sacrifice it in memory for object information to the same extent as Americans.

For this intermediate level, it is predicted that the effects of aging on cultural differences in cognition depend on task demands and instructions. For example, how precisely are participants instructed to attend to one stream of information or prioritize one process, or do they have flexibility to set their own priorities? Is the task sufficiently demanding such that participants cannot deploy culturally-preferred strategies but instead must rely on bottom-up processes? If the task requires high cognitive demands or instructions restrict the strategies that can be deployed, the effect of aging is predicted to be large, perhaps leading to smaller cultural differences with age. These types of situations are particularly difficult to account for using the Park et al. (1999) model. Considering factors such as task instructions and demands can account for the previous visual processing findings (Chee et al., 2006; Goh et al., 2007). When participants were given more detailed instructions (i.e., instructing them to attend to objects), older Singaporean adults showed a robust object adaptation response, indicating their boosted sensitivity to objects as is the case for Americans, compared to when they passively viewed stimuli and were free to adopt other strategies. This finding demonstrates that the cultural effects in older adults are reduced when task instructions are specific, limiting how much individual variation in motivation and engagement could contribute to top-down processing.

When tasks rely heavily on bottom-up processes (i.e., lower-level processes, such as vision), there is little ability to use strategies based on motivations and experiences; rather, people will primarily rely on task-dependent resources, such as sensory processing and speed of processing. Because these resources are generally reduced by neurobiological aging, similar performance on the task is predicted for older adults across cultures. An example task could include stimuli with different levels of visual contrast (i.e., the difference between black and white information). Contrast sensitivity changes with age such that low contrast stimuli are particularly hard to detect; this would be expected to be consistent across cultures due to neurobiological changes to the visual system. Fig. 3 shows these different patterns of cultural effects depending on top-down and bottom-up processes.

In summary, Gutchess and Gilliam (2022) revised the Park et al. (1999) model by focusing on the extent to which top-down or bottom-up processes are involved in a task. Rather than focusing on the discrete distinction between automatic (i.e., no cognitive resource demands) and controlled processing (i.e., some cognitive resource demands) as in the Park et al. (1999) model, the revised model focuses on the interplay of top-down and bottom-up processes on a continuum, emphasizing the roles of resource demands. The revised model also emphasizes task flexibility, in that multiple strategies, goals, knowledge, and motivations can support or influence

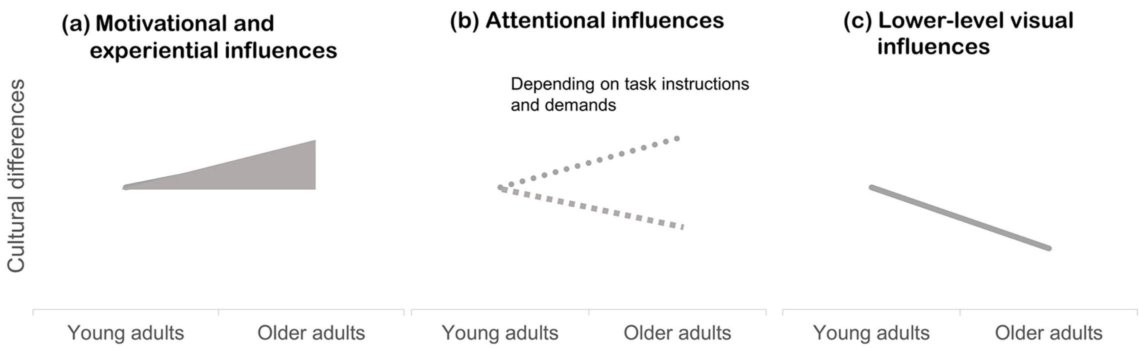

Fig. 3. The Gutchess & Gilliam (2022) model makes different predictions for the nature of cultural differences with age in adulthood, depending on top-down vs. bottom-up processes: (a) for motivational and experiential influences that heavily draw top-down processes, the graph depicts the range of possible cultural difference outcomes (i.e., from maintenance to magnification), (b) for attentional influences, the possible outcomes (i.e., magnification or reduction) depends on task instructions and demands, and (c) for lower-level visual influences that draw primarily on bottom-up processes, cultural differences are expected to be reduced.

task performance. Such modifications seem to better incorporate some previous findings that challenge the Park et al. (1999) model. For instance, the model claimed that automatic processes should be well-practiced throughout one's life and thus do not demand cognitive resources. However, processes deemed automatic in Park et al. (1999) (e.g., passive visual processing in Goh et al., 2007) appeared to interact with cognitive resources or task instructions in subsequent studies (e.g., Chee et al., 2006).

Introduction of a new Model: Considering cognitive resources and a lifespan perspective

By considering the role of top-down versus bottom-up processes, the Gutchess and Gilliam (2022) model reconciles some findings that cannot be easily explained by the Park et al. (1999) model. The current model revises and expands their model to better capture how the effects of culture on cognitive processes change across the lifespan, in the ways described below.

First, although the Gutchess and Gilliam (2022) model discussed the role of cognitive demands only in the attentional influences middle level of the model, the current model proposes that the moderating role of cognitive demands extends to top-down processes in general through the integration of motivational and experiential influences with attentional ones. This is because compared to bottom-up processes, top-down processes generally are influenced by task-relevant factors such as difficulty and instructions while individuals integrate, organize, and manipulate inputs. The integration of attentional and top-down processes with an emphasis on the role of cognitive resources can better reconcile previous findings (e.g., Yang, Chen, Ng, & Fu, (2013)). This will be addressed in the later section "Consideration of the Role of Cognitive Demands in More Top-down Processes".

Second, the current model expands on the previous models by integrating existing findings from early childhood with those from adulthood. Thus far in the field of culture and cognition, research typically has been conducted separately for childhood and late adulthood, and the previous models addressing the joint effects of culture and age on cognition (i.e., Gutchess & Gilliam, 2022; Park et al., 1999) focus on adulthood only. This makes it difficult to account for the continuous trajectories of cognitive development as well as the continually changing experiential factor of culture across the lifespan. For example, what if there are nonlinear changes in the development of cognitive resources or sensitive periods for the effects of culture on cognitive development? This lifespan model necessarily acknowledges cognitive resources as a critical factor that must be accounted for in understanding the joint effects of culture and age on cognition. Conceptualizing how culture affects cognition must consider the effects of both developing resources in childhood and losing resources with adult aging. Integrating the childhood and late adulthood literatures will help to elucidate the underlying mechanisms that account for cultural influences on cognition. Including studies of child development in the model has the potential to expand our understanding of how culture shapes cognition. For example, children's cognitive resources to perform a task are still developing and they might not yet have enough exposure to fully accumulate and internalize cultural knowledge, practice, and experience. Neither of the two previous models (i.e., Park et al., 1999; Gutchess & Gilliam, 2022), considered such an early stage, which prevents us from fully characterizing cultural effects on cognition.

The current model therefore makes different predictions about how culture and age interact with each other in cognitive processes depending on (a) the extent to which top-down versus bottom-up processes are involved in a task, instead of separating these into three levels as Gutchess and Gilliam (2022) proposed, and (b) for top-down processes, the degree of cognitive demands required to perform a task. In developing and evaluating this model, we adopt a lifespan perspective, reviewing empirical findings not only from adulthood but also early childhood. Because the current work focuses on how cultural effects on cognition differ with age, rather than when cultural differences on cognition start to appear, we restrict the scope of the literature review to empirical findings that compare multiple (at least two) age groups. That means that studies investigating cultural influences on cognition based on the study of a single age group (e.g., Xu et al., 2020) are not included in the review. For adulthood, previous studies compared younger and older adults, and for childhood, previous studies primarily compared different age groups in early to late childhood; the few findings regarding adolescents will be discussed in the later "Limitations and Future Directions" section, due to a dearth of studies.

Different predictions depending on (a) top-down vs. Bottom-up processes and (b) cognitive demands

Although any cultural influences are formed by experiences, thereby top-down influences, and all cognitive processes include a combination of top-down and bottom-up processing, the current model makes a distinction between top-down vs. bottom-up tasks depending on the extent to which each process is involved in task performance. Cognitive tasks heavily relying on top-down processes have greater flexibility through the use of prior knowledge, motivation, goals, experience, and preferences during task performance. How individuals interpret the world can be shaped by culture and those ideas and strategies perhaps reinforced as they live longer within a specific culture, by explicitly and implicitly learning culture-based processes from other members of society, including peers, caregivers, and teachers, through rules, norms, and reinforcement, and through prolonged experiences and practice. Thus, cultural differences in tasks that involve more top-down processing are predicted to enlarge, or at least be maintained, with age over the adult lifespan.

By contrast, for tasks involving more bottom-up processes, they have less flexibility for strategies, knowledge, and motivation to shape one's performance; rather individuals rely more on data- or sensory-driven information processing. It does not mean, however, that the more bottom-up tasks are insusceptible to cultural influences (e.g., cross-cultural differences in looking patterns during scene perception in Chua et al., 2005). In these tasks, when cultural differences are present for young adults, such differences are predicted to be eliminated with age in older adulthood. This prediction reflects the cognitive resource demands of bottom-up tasks with less use of culturally-saturated strategies that can compensate for the cognitive demands. Due to the declines in cognitive resources with age (Deary et al., 2009; Salthouse, 2009), large effects of age are expected to be more powerful than the effect of culture, leading to the convergence of cultural effects with age.

In young childhood, because children's cognitive processes are more influenced by their environments (e.g., interactions with caregivers or peers, observation of others, educational settings, visual ecology) as they develop (Chan, 2004; Doebel & Lillard, 2023; Koşkulu-Sancar, van de Weijer-Bergsma, Mulder, & Blom, 2023; Oh & Lewis, 2008; Rothbaum, Pott, Azuma, Miyake, & Weisz, 2000; Senzaki, Masuda, & Nand, 2014; Valsiner, 1987), cultural differences are predicted to increase with age in general, regardless of the degree of top-down and bottom-up processing required to perform a task. However, we believe it would take more time developmentally for top-down processes, compared to bottom-up processes, to reflect effects of culture. For top-down processes, higher-level components of culture, such as knowledge, strategies, expectations, values, and experiences, are abstract and learned over prolonged periods. By contrast, sensory habits can be developed via interaction with caregivers (e.g., eye contact; Haensel et al., 2020) or due to cultural differences in environments including climate and landscapes (Chang et al., 2011). Such bottom-up processes can be learned through simple exposure to sensory or stimuli-dependent inputs (Açık et al., 2010; Jasso & Triesch, 2007; although note that bottom-up processes can also be learned via experience and exposure, e.g., perceptual and sensory training). Thus, bottom-up processes are expected to influence individuals' cognitive processes even early in one's life and persist with age throughout adulthood, whereas top-down processes are expected to impact one's cognitive processes later, with effects emerging in a gradual fashion.

Importantly, for more top-down processes, there is another factor that can differentially influence the effects of age and culture on cognition: cognitive demands.[2] As Park et al. (1999)'s model states, resources such as speed of processing, working memory, and inhibition contribute to performance of cognitive tasks (e.g., mental computation; attention to one element while ignoring another; encoding information into memory). If a task has high cognitive demands, it is predicted that the cultural difference will be reduced with age in adulthood because the flexibility to exert cultural variation in strategies is limited due to reduced cognitive resource capacities as a result of neurobiological aging. Therefore, the relative effects of culture will be smaller than the age effects (i.e., age-related declines of cognitive resources), leading to the reduced cultural effects with age. By contrast, if a task requires fewer cognitive resources to perform, cultural effects on cognition are predicted to increase as people age in adulthood. For example, a pattern whereby younger adults do not differ across cultures but prominent cultural differences occur for older adults is possible because younger adults might have enough cognitive capacity to overcome the challenges of a task that works against their culturally-preferred strategies or relies on a strategy that is not well practiced. Older adults, however, might not have enough cognitive capacity to adopt a novel strategy or adjust from using a less effective one, thereby allowing cultural differences to emerge in older adults (Na, Huang, & Park, 2017).

For childhood, the trajectory would differ, albeit drawing on the same underlying mechanisms. In general, cultural differences should increase with age over early childhood. This is because during this time frame, children undergo socialization, internalizing social values, expectations, and beliefs, allowing them to acquire culture. However, if a task requires high levels of cognitive resources (e.g., mental computation), cultural differences would be expected to decrease with age in late childhood. This change in the trajectory would occur when children undergo dramatic cognitive growth, which is a universal change across cultures that occurs in late childhood (e.g., 6 to 12 years of age: Anderson, 2002; Romine & Reynolds, 2005; and see Korzeniowski, Ison, & Difabio de Anglat, 2021 for a review), including expansive growth of the frontal lobes during (pre-) adolescence (Kwon & Lawson, 2000; Tanaka et al., 2013). This could lead to more culturally-invariant performance; as children's cognitive resources rapidly develop and become mature enough to handle the cognitive demands of successfully implementing a culturally less familiar or nonpreferred strategy, then the relative effects of culture would be smaller than the age effects. This would lead to decreased cultural effects with age in later childhood due to the same underlying mechanisms as we predicted for adulthood. Therefore, we predict an inverted U shape with age for cultural effects in childhood.

For tasks that require fewer cognitive resources to perform, then the effect of culture on cognition is predicted to magnify with age due to acquiring more practice and internalization of the culturally-based strategies throughout childhood. Although this is similar to what we predict for adulthood, the predictions are slightly different in that young adults may not show cultural differences in culturally-saturated tasks with lower cognitive demands, whereas children could evidence differences in performance for such tasks. This is because unlike young adults, cognitive resources are still developing in childhood and are not yet as mature as young adults'; this may result in cultural differences in childhood on tasks even with low cognitive loads. The precise timing, and when "young childhood" can be distinguished from "older childhood" would depend on the timeline for developing a specific cognitive ability (e.g., numeracy, sense of self). See Fig. 4 for a summary for predictions for childhood contrasted against those for adulthood.

To examine whether the predictions of the model are plausible, we review the findings of previous studies that compared the performance of multiple age groups on cognitive tasks. We classify cognitive tasks that rely on more strategic processes based on social and experiential knowledge, beliefs, and habits as top-down. These tasks include those discussed as having strong motivational, experiential, and attentional influences in Gutchess and Gilliam (2022) and culturally-saturated tasks in Park et al. (1999) model: self-related cognitive tasks (e.g., autobiographical memory, self-referencing memory task), memory and social cognition tasks relying on culturally-saturated strategies, such as categorization or different patterns of attention (e.g., facial emotion recognition relying on focal

[2] Although cognitive demands can also be manipulated in bottom-up tasks (e.g., having distractors, increasing the complexity of sensory stimuli), the current model does not focus on the manipulation of cognitive demands in bottom-up tasks for the following reason. In addition to scarce research with bottom-up tasks, there have been no studies with bottom-up tasks varying in cognitive demands in the field of age, culture, and cognitive psychology. Therefore, it is challenging to test the model with previous findings. In terms of predictions on cultural effects on cognition with age, however, the logic underlying bottom-up tasks is that the age-related declines in cognitive resources would make the age effects larger compared to the cultural effects, leading to the convergence of cultural effects with age. Therefore, regardless of cognitive demands, reduced cultural effects with age in bottom-up tasks are expected in general.

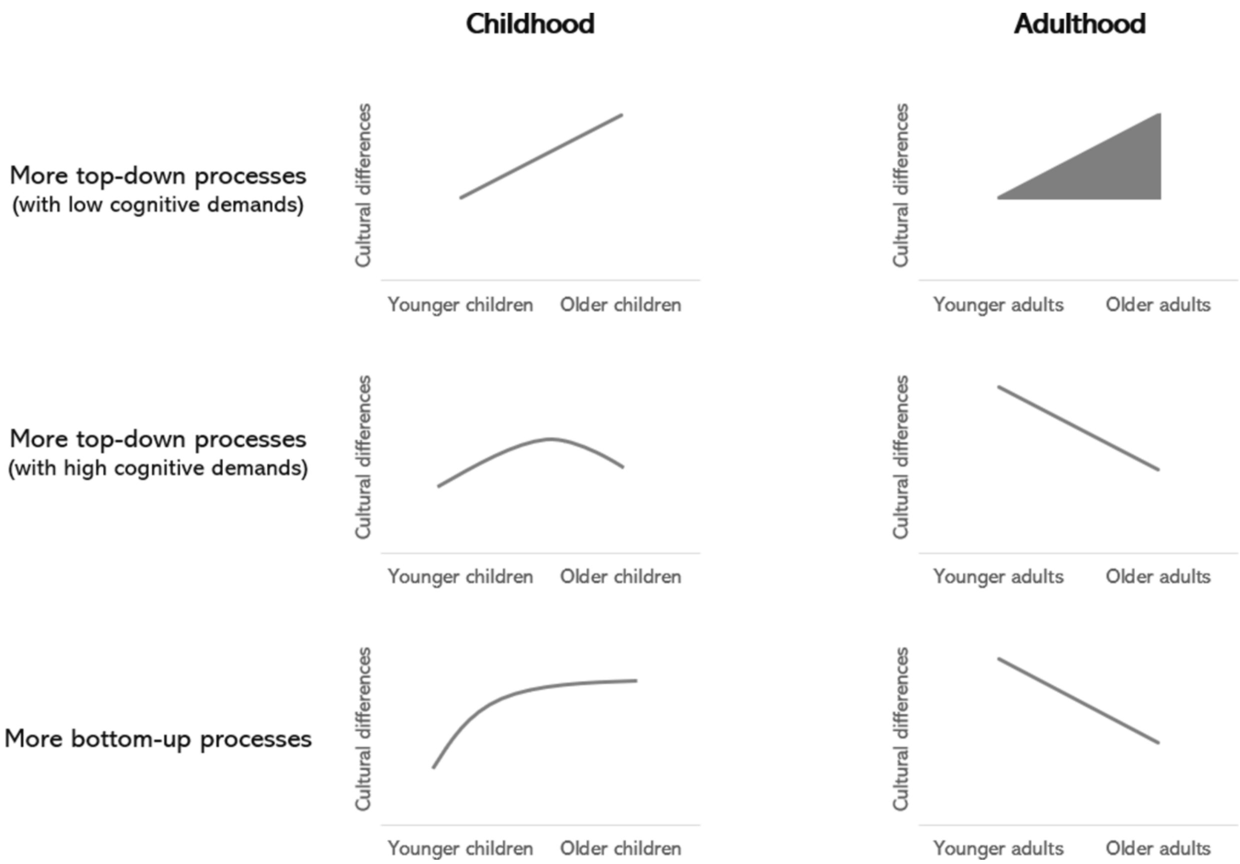

Fig. 4. Summary of how cultural differences in cognition change with age for childhood (left) and adulthood (right), separately. Notes – Regarding the predictions on tasks requiring “more top-down processes (with low cognitive demands)” for adulthood (i.e., top-right panel), it is challenging to set specific criteria that identify when cultural effects become larger with age and when they maintain with age based on the existing literature. Nevertheless, the cultural effects are assumed to not be reduced.

information vs. contextual information, scene description, memory for object vs. background, framed-line task, global–local task), and computational cognitive tasks that require mentally manipulating and constructing information that involve culturally-saturated strategies (e.g., executive function tasks for which cross-cultural differences are observed; Sabbagh et al., 2006; Oh and Lewis, 2008). Tasks classified as relying on bottom-up processing include cognitive tasks that do not support culturally-saturated strategies (e.g., culture-invariant tasks discussed in Park et al. (1999); visual processing tasks involving lower-level visual features (e.g., color, edges, brightness), or measuring spontaneous responses (e.g., eye-movements while processing visual stimuli). We again acknowledge that the classifications are relative, reflecting a continuum of processes that are more or less top-down or bottom-up. Next, we will

Table 1
Example tasks with more top-down processes (manipulating the levels of cognitive resources) vs. bottom-up processes.

Process types	Examples
Tasks with more *top-down* processes *cognitive tasks relying more on higher-level internal guidance, thereby having greater flexibility to use culturally-saturated strategies, knowledge, and motivation*	self-referencing memory tasks (e.g., Zhang et al., 2020), autobiographical memory tasks (e.g., Wang, 2004, 2008; Peterson et al., 2009), categorization memory tasks (e.g., Gutchess et al., 2006), attention or memory for focal vs. contextual information or absolute vs. relative information (e.g., Duffy et al., 2009; Goh et al., 2007; Imada et al., 2013; Ko et al., 2011; Senzaki et al., 2016), some executive function tasks for which culturally-saturated strategies (e.g., inhibitory control, cognitive efficiency) are used (e.g., Demetriou et al., 2005; Ellefson et al., 2017)
Tasks with more *bottom-up* processes *cognitive tasks relying more on a lower-level sensory stimulus, thereby having less flexibility to use culturally-saturated strategies, knowledge, and motivation*	tasks involving lower-level visual features (no previous studies) and visual contrast (no previous studies), spontaneous response tasks (e.g., Haensel et al., 2020; Kelly et al., 2011; Senju et al., 2013)
Examples of how to manipulate *cognitive demands*	recall vs. recognition (no previous studies), item memory vs. source memory (e.g., Chua et al., 2006; Yang et al., 2013), categorical memory for strongly associated words vs. for weakly associated words (e.g., Gutchess et al., 2006), single task vs. dual task (no previous studies)

review literature regarding cognitive demands. Please see Table 1 for examples of tasks with more top-down (varying the levels of cognitive demands) vs. bottom-up processes.

To summarize, we evaluate the current model by examining previous literature regarding (1) the distinction of top-down versus bottom-up processes and (2) the role of cognitive demands in top-down processes. The literature review includes not only adulthood but also childhood. Please see Table 2 for summary of the literature reviewed comparing different age groups in this section of the paper.

Table 2
Summary of the literature reviewed in the current paper. The literature is organized with adulthood first and in a chronological order.

First author's name (year)	Participants' age group	Culture group	Cognitive ability	Results on cultural differences with age (i.e., increased, maintained, decreased with age?)
Levy & Langer (1994)	Adulthood	Chinese vs. American	More top-down: Memory	Increased (i.e., no cultural differences in YA, cultural differences in OA)
Yoon et al. (2000)	Adulthood	Chinese Canadian vs. Anglophone Canadian	More top-down: Memory	Increased (i.e., no cultural differences in YA, cultural differences in OA)
Hedden et al. (2002)	Adulthood	Chinese vs. American	More top-down: Verbal cognitive tasks (expected to be culturally-saturated)	Maintained (i.e., Digit span task – forward) or the culture x age interaction (i.e., reversed patterns between YA and OA; Digit comparison task)
			Less top-down: Visuospatial cognitive tasks (expected to be culturally-invariant)	No cultural difference; Age differences (i.e., Pattern comparison task, Corsi blocks task)
Chua et al. (2006)	Adulthood	Chinese vs. American	Less cognitively-demanding: item memory (Exp 2)	Increased (i.e., no cultural difference in YA, cultural difference in OA)
			More cognitively-demanding: source memory (Exp 1 & 2)	No cultural difference; Age differences
Gutchess et al. (2006)	Adulthood	Chinese vs. American	Less cognitively-demanding: categorization strategy for memory in weak categorical associations	Increased (i.e., no cultural differences in YA and cultural differences in OA)
			More cognitively-demanding: categorization strategy for memory in strong categorical associations	No Age x Culture interaction (i.e., significant main effects of age and culture)
Ko et al. (2011)	Adulthood	Korean vs. American	More top-down: attention to focal objects vs. contextual background	Decreased
Yang et al. (2013)	Adulthood	Chinese vs. Canadian	Less cognitively-demanding: item memory	Increased (i.e., no cultural difference in YA, cultural difference in OA)
			More cognitively-demanding: source memory	No cultural difference; Age differences
Na et al. (2017)	Adulthood	Singaporean vs. American	Less cognitively demanding: a typicality task	Increased (i.e., no cultural differences in YA and cultural differences in OA)
Gutchess & Boduroglu (2019)	Adulthood	Turk vs. American	More top-down: Categorical memory error (expected to be culturally-saturated)	Maintained
			Less top-down: Semantic memory errors (expected to be culturally-invariant)	No cultural difference; Age differences
Zhang et al. (2020)	Adulthood	Taiwanese vs. American	More top-down: Self-referencing memory	Increased
Wang (2004)	Childhood	Chinese vs. American	More top-down: Autobiographical memory	Increased
Wang (2008)	Childhood	Chinese vs. American	More top-down: Autobiographical memory	Increased (i.e., becoming more adapted to a specific culture such that the memory of Chinese immigrant children in the US becomes more similar to European Americans and diverged from Chinese children in China with age)
Peterson et al. (2009)	Childhood	Chinese vs. Canadian	More top-down: Autobiographical memory	Increased
Duffy et al. (2009)	Childhood	Japanese vs. North American	More top-down: the framed line test	Increased
Imada et al. (2013)	Childhood	Japanese vs. American	More top-down: tasks related to context sensitivity	Increased
Senzaki et al. (2016)	Childhood	Japanese vs. Canadian	More top-down: a task related to objects vs. contexts	Increased (when they did the task with a parent)
Kelly et al. (2011)	Childhood	Chinese vs. British	More bottom-up: gaze patterns during face processing	Cultural differences even in the youngest age group
Senju et al. (2013)	Childhood	Japanese vs. British	More bottom-up: gaze patterns during face processing	Cultural differences in young children (i.e., 1-to-7-year-olds)
Haensel et al. (2020)	Childhood	Japanese vs. British	More bottom-up: gaze patterns during face processing	Cultural differences in infants (i.e., 10- and 16-month-olds)

Reviewing the literature on top-down vs. Bottom-up processes

Evaluating the Evidence in Adulthood. Of the existing studies comparing younger and older adults' performance on cognitive tasks that rely on top-down processing, the findings overall support the prediction that cultural differences will increase, or at least be maintained, with age (Gutchess and Boduroglu, 2019; Hedden et al., 2002; Levy and Langer, 1994; Yoon et al., 2000; Zhang et al., 2020). For instance, Levy and Langer (1994) and Yoon et al. (2000) examined the relationship between cultural differences in stereotypes of aging and memory performance. In both studies, no cultural difference in performance on memory tasks emerged for younger adults, whereas older adults' performance differed across cultures, indicating prominent cultural differences in older adults. Levy and Langer (1994) compared groups that varied in the negativity of their stereotypes about aging, with Chinese hearing and American Deaf adults expected to hold more positive views of aging than American hearing adults; they furthermore predicated that aging stereotypes would relate to older adults' performance on memory tasks. Results revealed that younger adults' performance was comparable across cultures, whereas older Chinese adults' memory performance was higher than that of the two American groups, with the American hearing group with the lowest memory score. Path analyses indicated that positive views of aging could mediate influences of culture on memory performance, indicating a way in which top-down processes could influence performance on a demanding episodic retrieval task. In a conceptual replication, incorporating additional memory tasks, Yoon et al. (2000) compared the performance of young and older Canadians and Chinese Canadians (who had lived in Canada less than 5 years) on four non-verbal memory tasks. According to Yoon et al. (2000), two of the memory tasks were possibly biased to Chinese Canadian participants because the visual stimuli in the tasks may be similar to Chinese written characters, whereas the other two tasks were not culturally biased tasks. In general, young adults outperformed older adults regardless of culture, but interestingly, in the two tasks thought to be culturally-biased, a cultural difference emerged for older, but not young, adults, such that older Chinese Canadians outperformed Canadian older adults. Taken together, the results support the idea that cultural effects on memory can be larger with age when tasks involve more top-down processes (e.g., using culturally-saturated strategies).

Other studies using tasks with different levels of top-down processing find similar patterns. As reviewed in an earlier section, Hedden et al. (2002) found interactions between culture and age for verbal cognitive tasks (expected to be culturally-saturated) in that cultural differences found in younger adults were maintained or increased for older adults. For visuospatial measures of cognitive tasks (expected to be culturally-invariant), only age effects emerged. Zhang et al. (2020) explored how the cultural differences in memory benefits from relating information to the self differ with age by comparing young and older adults from the U.S. and Taiwan. Results of this self-referencing memory task, believed to rely on top-down processes, demonstrated that young Taiwanese, young Americans, and older Americans exhibited similar self-referencing effects on memory (i.e., better memory on the adjectives presented in the self condition compared to comparison conditions). Older Taiwanese, however, had a smaller self-referencing effect, suggesting that cultural differences in self-referencing memory increase with age. By contrast, the neuropsychological measures of cognition were largely culturally-invariant, but sensitive to age-related declines in performance. The results from Gutchess and Boduroglu (2019) also are consistent with our predictions. This study investigated how cultural differences in memory errors change with age, comparing the performance of younger and older adults from the US and Turkey on a cued recall task and comparing the types of memory errors made by participants. Categorical memory errors were believed to be culturally-saturated based on previous findings of cultural differences in young adults (Gutchess et al., 2006; Schwartz, Boduroglu, & Gutchess, 2014) such that people from the West display their preference for using categorization strategies in memory compared to people from the East. Results illustrate that cultural differences in categorical memory errors persist with age such that the cultural differences were observed in both younger and older adults. In contrast, the tendency to commit semantic errors (e.g., recalling synonyms or related words that do not share a specific relationship with the cue) may reflect more general changes with age, rather than relying on culturally-saturated strategies (i.e., categorization or taxonomy). For these types of errors, age-related declines were observed that were consistent across cultures.

Due to a lack of studies investigating the combined effects of age and culture on more bottom-up processes in adulthood, we are not able to evaluate these predictions of this model. This is a ripe area for further research across cultures.

Evaluating the Evidence in Childhood. As in the literature review on adulthood, the existing studies that compare multiple age groups in childhood suggest that cultural differences in cognitive processes are more prominent at older ages. For instance, how children organize their identity and autobiographical memory when being interviewed can differ across culture such that European American children are more likely to mention their personal internal states (i.e., attitudes, behaviors, beliefs) in an independent manner when describing themselves (e.g., "I am smart"), whereas Chinese children are more likely to discuss the self in terms of the demographic groups that they belong to (e.g., "I am from Beijing") and their relationships with others (e.g., "I like hanging out with my friends and they really like me") (Wang, 2004). Such cultural differences become more prominent as children age; cultural differences in self-description were not observed in younger children (i.e., preschoolers, kindergartners) but were observed in older children (e.g., second graders). Regarding age-related increases in cultural differences, Wang (2004) noted that enculturation throughout daily interactions between parents and children occur as they share more and more activities. Through these interactions, cultural values and beliefs are transmitted to children, thereby impacting how they organize information and view themselves. The pattern of greater cultural differences with age was also found in autobiographical memory. European Canadian children and Chinese children were asked to recall past events. Corresponding to previous evidence that individuals from the West have tendency to report earlier and more childhood memories compared to East Asians (MacDonald et al., 2000; Wang, 2001; Wang et al., 2004), European Canadian children reported earlier ages of their first memory and a greater number of events compared to Chinese children in China (Peterson, Wang, & Hou, 2009). These cultural differences magnify with age (i.e., comparing ages 8, 11, and 14). These effects could reflect cultural differences in the focus of parent–child conversation patterns, with East Asians focusing more on social norms, group activities, and other people and Westerners focusing more on the self and elaboration of details. (Ross & Wang, 2010; Wang, 2004, 2011).

Further probing the characteristics of autobiographical memory, Wang (2008) compared Chinese children in China, Chinese children who immigrated to the U.S., and European-American children in the U.S. with a longitudinal study design from age 3 to 4.5. Cultures differed in the specificity of memory and use of language to describe internal states, with Chinese and Chinese immigrant children conveying less specific information and using internal state language less than European-American children at age 3. By age 4.5, however, Chinese immigrant children's memory specificity and use of internal state language became similar to European American children, and diverged from that of Chinese children in China. The results imply that cultural influences in more top-down processes emerge gradually over time as children get older and have more shared activities with people in a specific culture.

Developmental trajectories showing cultural differences for more top-down processes also can be observed in how attention is allocated to objects and background contexts. Children completed the framed line test, in which participants see a square containing a line and then need to draw a line in another square that is either the same size or smaller or larger than the first square. In the absolute condition, participants were instructed to draw a line that has the same length of the line in the first square while ignoring the relative ratio of the first square and its line. In the relative condition, however, participants were instructed to draw a line in the second square that has the same relative ratio of the line in the first square while ignoring the absolute length of the line. Results from children aligned with previous findings (Kitayama et al., 2003; Hedden et al., 2008), demonstrating that East Asians committed more errors in the absolute condition than in the relative condition, whereas individuals from the West showed the opposite pattern, North American and Japanese children between the ages of 6 to 8 and 9 to 13 exhibited error patterns corresponding to their culture (Duffy, Toriyama, Itakura, & Kitayama, 2009). However, such cultural differences were not found in younger children (i.e., 4- to 5-year-olds). Similarly, cultural differences in context sensitivity also enlarge with age in childhood. Children's sensitivity to context was measured using a free description task, in which children were prompted to freely describe a photo after seeing it, and the Ebbinghaus illusion task, in which children had to judge which circle out of the two looked bigger in either illusional contexts or no context. For these tasks, Japanese children (aged 4 to 9) demonstrated greater sensitivity to contexts, demonstrated by mentioning background, rather than focal objects, more often in the free description task and showing greater contextual illusions in the Ebbinghaus illusion task, compared to Americans (Imada, Carlson, & Itakura, 2013). The cultural differences in context sensitivity were observed in older age groups (i.e., ages 6–7 and 8–9; with larger cultural differences in children aged 8–9, compared to children aged 6–7), but not in a younger age group (i.e., ages 4–5).

Cultural differences may be shaped through socialization with caregivers as children's sociocognitive abilities develop with age (Imada et al., 2013; Wang, 2004). This speculation is supported by the findings of Senzaki et al. (2016) that explored how culture promotes cultural differences in cognitive processes (i.e., sensitivity to contexts vs. objects) in relation to socialization. In this study, Canadian and Japanese 4- to 9-year-old children described scenes either by themselves or with their parents. When they did the task alone, there was no cultural difference between Canadian and Japanese children, whereas when they did the task with a parent, cultural differences emerged for older (i.e., aged 7–9), but not younger (i.e., aged 4–6), children. The results indicate that younger children have not yet attained developmental levels that enabled them to incorporate inputs from their parents, unlike performance at later ages (Senzaki et al., 2016). These findings imply that cultural differences in more top-down processes enlarge with age in children and can reflect development in the ability to incorporate and internalize input from caregivers.

Although there is a dearth of research on more bottom-up processes in adulthood, the literature on more bottom-up processes in childhood, such as face perception, indicates that cultural differences can appear at early stages of one's life and persist with age, throughout adulthood. For example, culture-specific patterns of eye gaze occur during face perception such that individuals from East Asia tend to fixate on the nose, whereas individuals from the West tend to fixate on the eyes and mouth (Blais et al., 2008). This may reflect cultural differences in information sampling strategies in that individuals from East Asia tend to have a global strategy to collect information, looking at the center of the face, whereas individuals from the West tend to have a local strategy to collect information, directly looking at the eyes and mouth (Miellet et al., 2013). A series of eye-tracking studies comparing multiple age groups illustrated that such cultural differences in gaze patterns can be found early in life. Initial findings (Kelly et al., 2011) with 7- to 12-year-old children from China and the UK found that the cultural differences were observed even for their youngest age group (i.e., ages 7–8). Later research extended findings to younger children, showing that even infants display culture-specific gaze patterns (Haensel et al., 2020; Senju et al., 2013). That is, young children's (i.e., 1- to 7-year-olds) eye gaze patterns were similar to adults' pattern (Senju et al., 2013) and cultural differences in gaze patterns during face perception were observed in 10- and 16-month-old infants (Haensel et al., 2020). Finding such cultural differences at a very early age is striking, but the exact underlying mechanisms are still unclear. One potential mechanism (Johnson, Senju, & Tomalski, 2015; Morton & Johnson, 1991) suggests that two processes might be involved. One is that at a very early age, infants display predisposing preference for faces or face-like stimuli via the subcortical route. The other is that around two months of age, infants learn and acquire other specialized face processing via the cortical route. Aligning with this, it is possible that humans learn how to perceive and process the surrounding social world at a very early age (i.e., after 2 months) through experience (e.g., interacting with other people and environments surrounding them; see Pascalis et al., 2005) and as their cortical brain develops. This experiential learning could induce culturally-saturated ways to process faces.

These findings suggest that such cultural differences are formed at a very early stage of one's life and persist with age. The pattern is in line with evidence that lower-level attentional control starts to develop even during infancy and becomes mature in early childhood (Anderson, 2002). However, the literature reviewed is about face perception, which may be a distinct domain (Kanwisher & Yovel, 2006; Yovel & Kanwisher, 2004) that could have a developmental trajectory that differs from other bottom-up perceptual processes. For instance, when comparing eye movements (i.e., fixations, saccades) of American and Mayan infants (i.e., 1- to 2-year-olds), children (i.e., 6- to 7-year-olds and 9- to 10-year-olds), and adults while watching real-world videos, Mayan and American infants showed the same eye movement patterns such that the eye movement patterns (i.e., fixation duration, saccade amplitude) changed independently in response to the video's contents. At around age 6, however, the US participants' eye movement patterns diverged from Mayans' such that their patterns changed in response to the video's content. The results indicate that the bifurcation of cultures in visual attention occurs after age 6 (Kardan et al., 2017). Because data were not collected from children between these two age groups (i.e., from 2- to 6-year olds), it is unclear when the cultures begin to diverge in eye movement patterns for scene perception. However, it is notable how much later these cultural differences emerge compared to those for face perception, which were present even for 10-month-olds (Haensel et al., 2020). The finding nevertheless supports our prediction that cultural differences in more bottom-up processes could emerge at an early stage of one's life and then magnify (or at least persist) with age. More research beyond face processing, however, is necessary to test the current model.

We acknowledge that not all previous findings fit our predictions. For instance, Ko et al. (2011) examined how cultural differences in the degree of being influenced by emotional background scenes when rating the emotion of focal faces change with age. According to the definition and examples of top-down processes that we make in the earlier section, this emotion rating task would involve more top-down processes because it appears to rely on visual attention strategies that can be culturally-saturated (i.e., attending to focal vs. contextual information). Results, however, showed that Korean younger adults were more influenced by the emotional valence of background scenes when rating the emotion of focal faces compared to younger Americans, but such cultural differences were not observed for older adults. This is at odds with our prediction. One possibility is the moderating effect of cognitive demands, which we will discuss further in the next section. A task requiring participants to attend to focal emotional faces against a background scene may be particularly cognitively demanding for older adults, who have lower levels of contrast sensitivity and visual acuity (Derefeldt, Lennerstrand, & Lundh, 1979; Greene & Madden, 1987; Spear, 1993). This is because the background scene in color could be more salient than the focal faces, which were presented in black and white. Thus, processing focal faces in this task could tax cognitive resources, leading to the convergence of cultural groups with age.

Reviewing the literature relevant to cognitive demands in top-down processes

Evaluating the Evidence in Adulthood. When reviewing studies that allow us to compare performance on tasks differing in levels of cognitive demands, results appear to support our predictions. That is, for less cognitively-demanding tasks, cultural differences magnify or persist with age, whereas for more cognitively-demanding tasks, cultural differences decrease with age. However, this claim is based on comparing across studies, often which investigate different processes using different methods. The cross-cultural aging literature lacks studies that systematically manipulate the level of cognitive demands of a task (e.g., comparing performance on a 3-back vs, a 2-back working memory task) or the cognitive resources available to participants (e.g., completing a task under cognitive load vs. no load), or assess how individual differences in cognitive resource availability are associated with different patterns of cultural effects with age. We will return to this point in the Future Directions.

This caveat aside, comparing across studies generally supports the idea that cultural differences in memory for the less cognitively-demanding tasks, such as object or item only information, emerge only in older adults, but not in younger adults. In contrast, only effects of age, but not culture, were found for more cognitively-demanding tasks, such as object-background binding memory (Goh et al., 2007) and source memory (Chua, Chen, & Park, 2006; Yang et al., 2013). Although Gutchess and Gilliam (2022)'s model discussed the effects of cognitive demands only for the level of attentional influences, the role of cognitive demands (i.e., item memory vs. source memory) also was found for a memory task relying on a categorization strategy (Yang et al., 2013), which would be classified as motivational and experiential influences according to the Gutchess and Gilliam (2022) model. This finding seems to validate the current model that integrates motivational and experiential influences with attentional ones in considering how cognitive demands moderate the interplay of age and culture on cognition for top-down processes.

Comparisons of memory recall for categorically-related (less cognitively-demanding) versus unrelated (more cognitively-demanding) words or words that have stronger or weaker associations with categories (Gutchess et al., 2006) do not appear to support the idea that cultural differences in older adults' performance are limited to tasks that are less cognitively demanding. This is because there were only age differences, not cultural differences, in the number of words recalled (i.e., young adults > older adults) regardless of the level of cognitive demands. However, it may be the case that all of the tasks were sufficiently cognitively demanding, given the high levels of self-initiated processing that is necessary for free recall. When examining categorical clustering scores (i.e., the extent to which participants used categorization strategy for recall), cultural differences in the scores were found in older, but not young, adults for the less cognitively-demanding condition, whereas an interaction between age and culture was not observed in the more cognitively-demanding condition, perhaps supporting the current model. Although this example indirectly supports the moderating role of cognitive demands, as proposed in the new model, direct comparisons of tasks that are designed to differ in cognitive demands in a controlled fashion will be necessary to test the model.

In one of the only studies to integrate measures of cognitive function into comparisons of younger and older adults' cognition across cultures, Na et al. (2017) used a categorization task that compared judgments of typical and atypical exemplars. Typicality weighs strongly in an intuitive reasoning strategy, with people tending to respond more quickly to typical than atypical exemplars of a category. For instance, people are faster to judge that sparrows, a typical exemplar of "birds", have wings compared to judging that penguins, a non-typical exemplar of "birds", have wings. This intuitive reasoning strategy is used more by East Asians than Americans (Norenzayan et al., 2002). Na and colleagues assumed that this strategy requires low levels of cognitive resources (e.g., inhibitory control). For young and older Singaporean and American adults, results revealed an interaction between age and culture such that young adults performed comparably across cultures, but cultural differences were observed only for older adults, such that the cost to reaction times for atypical exemplars of a category was larger for Singaporean than American older adults. Furthermore, Na et al. (2017) found that the cultural differences for older adults were related to their levels of cognitive functioning, assessed through a battery of measures. Results were interpreted as suggesting that older adults' poorer cognitive functioning interacted with cultural values to lead to cultural differences in performance. Although this study does not compare performance on tasks with higher vs. lower levels of cognitive demand, the results are in line with our argument that cultural differences emerge with age primarily for tasks that have lower cognitive demands (i.e., in this study, use of an intuitive reasoning style). Thus, cognitive resource demands appear to be a critical factor influencing when cultural differences would be predicted to differ with age for adults.

Evaluating the Evidence in Childhood. Based on our search of the literature, there does not seem to be studies that manipulate the levels of cognitive demands in more top-down processes (e.g., culturally-saturated tasks) in childhood. Thus, it is challenging to directly test the predictions of our model with existing data. However, examining the developmental trajectories of cultural differences in tasks involving high levels of mental computational skills, such as executive function tasks, might indicate the role of cognitive resources. For instance, East Asian children display earlier development of executive functioning than those from the West, particularly for tasks demanding inhibitory control (Cho et al., 2021; Lan et al., 2011; Sabbagh et al., 2006; Oh & Lewis, 2008). This may occur because East Asian culture embraces Confucianism and its emphasis on collectivistic responsibility and harmonized social interactions while stressing the importance of controlling one's behaviors. These values may encourage children in the East to practice executive functioning more often in their daily lives compared to children from the West. However, cultural differences in performance on executive functioning tasks increase with age in early childhood (i.e., preschool period; Schmitt et al., 2019) but then decrease with age in late childhood (Demetriou et al., 2005; Ellefson, Ng, Wang, & Hughes, 2017). This pattern may reflect the rapid growth of cognitive capacity that occurs across cultures with age (i.e., greater age effects than cultural effects) during this developmental period and that can enable children to start to overcome the challenges of using culturally-unfamiliar and non-preferred strategies. Specifically, when measuring the executive functioning of 8-, 10-, 12-, and 14-year-old Chinese and Greek children, cultural differences in executive functioning decrease from the 8- to the 14-year-olds (Demetriou et al., 2005). When comparing 9- to 16-year-old children and their parents from Hong Kong and the U.K., cultural differences in executive functioning were observed in children, but not in their parents (Ellefson et al., 2017). These findings show that the culturally-invariant development of cognitive resources contributes to the convergence of performance across cultural groups late in child development. This pattern of findings provides indirect support for the importance of cognitive resources in the interplay of the effects of age and culture.

Some findings do not seem to correspond with our predictions. For instance, there is evidence suggesting that cultural differences in more top-down processes emerge in early childhood and persist with age (throughout late-adulthood), rather than emerging later in childhood and diverging (or persisting) with age. One example is global–local processing, which is assessed by having participants view stimuli that consist of a large (global) figure made of other small (local) figures. For example, the global shape of one target figure is a square consisting of small triangles as local elements; such stimuli can be used to set-up competition between global and local processing (Oishi et al., 2014). The researchers expected that Japanese individuals would be more likely to show local processing compared to Americans. When they tested cross-cultural differences in global–local processing between Japanese and Americans with adults (ages 20 to 69) and children (ages 4 and 6), they found that Japanese exhibited more local processing than Americans in adulthood, and that these cultural differences emerged even in 4-year-old children. The results suggest the cultural differences in cognitive processes involved in attention allocation were observed in early childhood and seem to persist with age. This pattern differs slightly from our predictions for top-down processes, for which we expect cultural differences to be found in later childhood and enlarge (or at least persist) with age. It may be the case that this global–local processing task engages less top-down and more bottom-up processing, particularly because the task merely requires a choice of which figure best matches the exemplar based on perception rather than requiring a response in a speeded task involving competition between multiple streams of information and mental re-organization of information. In this way, this task could differ substantially from those reviewed earlier in this paper, which seem likely to require more top-down processing (e.g., autobiographical memory, self-referencing memory, scene-description, the framed line task). To test this possibility, future studies would need study designs that systematically manipulate the degree of competition between local and global information, studied in a wide range of age groups, from young children to older adults. Similarly, Phillips et al. (2021)'s study is at odds with our model. They investigated the effects of age and culture on performance on the Tower of London task, an executive functioning task that emphasizes planning ability, by comparing younger and older adults from Malaysia and the U. K. Because the task requires higher-order cognitive abilities and involves frontal cortical networks (Shallice, 1982; Szczepanski & Knight, 2014), age effects should be larger than cultural effects (i.e., converging cultural differences with age) according to the current model. However, the results indicated increases in cultural differences with age.[3] Whereas no cultural differences were observed in younger adults, accuracy was significantly lower for Malaysian older adults compared to their British counterparts. However, some aspects of the results complicate the interpretation of the findings. For one, Malaysian older adults had lower scores on the Montreal Cognitive Assessment and a working memory test compared to their British counterparts. In addition, older Malaysians displayed not only lower accuracy but also slower reaction times on the Tower of London task, instead of showing speed-accuracy trade-offs. These anomalies in the data make it possible that differences in performance across cultures for older adults could reflect differences in the cognitive resources available for each sample, rather than cultural differences in strategy. As Park et al. (1999) advocated, it is imperative to match samples on cognitive ability to examine the joint effects of culture and age. Future studies with matched samples

[3] It is possible that the Tower of London task requires analytic skills, which might be favored more to Western people, rather than Easterners, so the results may appear to be in line with the current model (we thank the anonymous reviewer who raised this possibility). In the field of cross-cultural difference in cognition, however, analytic styles refer to thinking styles of focusing on focal parts and preferring logic, and they are used in the comparison of holistic styles referring to thinking styles of attending to contexts and relations. Considering these definitions used in this field, it is uncertain whether the Tower of London task is a culturally-saturated task via such analytic thinking styles because the task does not seem to involve a process of focusing on focal parts and using logic.

would be necessary to fully unpack these patterns of effects.

Limitations and future directions

Although we argue that considering cognitive demands is a critical factor in developing a theory to predict and account for cultural differences in cognition with age, there are several limitations to our current model. First, the model contrasts the effects of culture with age on top-down vs. bottom-up processes. As we acknowledged, cognitive tasks consist of a combination of top-down and bottom-up processes, making it challenging to clearly distinguish how much top-down processes and bottom-up processes are involved in a task. Although we attempt to delineate the types of processes that distinguish one from another, it is necessary to further validate the classifications.

Another factor emphasized in the model is the cognitive demands required to perform the task. These are also poorly defined; like top-down/bottom-up processing, they exist on a continuum. Without knowing the thresholds of cognitive resources, it is difficult to make clear predictions of how cultural differences would emerge with age. However, parametrically testing effects over multiple levels of difficulty or manipulating cognitive resource availability would offer enormous advances for the field. For example, performance on a cognitive task (e.g., an object memory task) could be assessed in a context that allows for individual and cultural variation in top-down processing (e.g., no instructions; testing memory for objects encountered in real life) vs. in a more bottom-up contexts (e.g., constrained instructions; testing memory for abstract figures). Cognitive resource demands could be manipulated by comparing single task vs. dual task performance, or by varying the speed of presentation or response windows.

Thus far, the scarcity of previous literature that manipulates cognitive demands in culturally-saturated tasks makes it difficult to assess this aspect of the model using existing research. Although Na et al. (2017) investigated the role of cognitive resources and how cultural differences emerge for a culturally-saturated task with lower cognitive demands, there was no comparison with a task with higher cognitive demands, making it unclear how the level of cognitive demands moderate the interplay of age and culture. There is a tremendous opportunity for future studies to directly compare the top-down vs. bottom-up processes and higher vs. lower cognitive demands to test the model. Such an approach, with a focus on targeting specific and well-studied cognitive processes, would substantially advance the literature. The potential for such an approach would be even greater if combined with an individual difference approach, including large samples of participants who complete neuropsychological measures. Such an approach could make an additional contribution by identifying which cognitive resources, such as executive function, speed of processing, or, for older adults, cognitive reserve developed through life experiences (as in Stern, 2009) underlie the different patterns of cultural differences across age groups.

In addition, including diverse age groups will be essential to better understand cultural effects on cognition across the lifespan. Most of the previous literature focuses on children and younger adults, and little is known about how culture interacts with age in terms of cognitive processes in adolescence. This is an important life stage due to the occurrence of neurobiological, cognitive, and emotional maturation (Konrad, Firk, & Uhlhaas, 2013), and evidence for sensitive periods for individual differences (Fuhrmann, Knoll, & Blakemore, 2015). In addition, middle-aged adulthood is of interest because it is a period largely influenced by sociocultural factors (Willis & Martin, 2005); however, this life stage has largely been neglected in developmental psychology (Lachman, 2015). Although we present some studies of older adults, there are relatively few, and samples tend to be on the younger side (60 s and early 70 s). Late adulthood, from the later 70 s and beyond, is a period greatly influenced by neurobiological change (Lu et al., 2004; Scahill et al., 2003); motivation and life goals can also change during this period (Carstensen, 1992). Important, yet lofty, goals for future research include investigating lifespan samples from infancy or childhood (depending on the nature of tasks) to older adulthood in a single study, using longitudinal designs to assess change over time within the same individuals to isolate true developmental processes (e.g., as opposed to cohort effects), and using comparable tasks across multiple age groups. By doing so, it enables us to move forward from the current model that makes separate predictions for childhood and adulthood —- with a gap between older children and young adults —- to a more continuous life stage model.

In addition, going beyond East-West comparisons is imperative to better understand cultural effects on cognitive processes and their patterns with age. For instance, studying a greater variety of nations beyond those classified as Eastern or Western and studying different cultural groups within a nation (Dotson & Duarte, 2020; Gutchess & Rajaram, 2023; Kitayama & Salvador, 2024; Talhelm et al., 2014; Talhelm & Dong, 2024; Vignoles et al., 2016) will help to elucidate what specific cultural factors and experiences are relevant to differences in cognition. Importantly, such research will help to understand what patterns of cognitive aging would be expected to generalize across cultures or be culture-specific.

Another route for future directions could be delving into the joint effects of age and culture on emotional processing (see also Gutchess & Cho, 2024). Although the current paper discusses some findings of cross-cultural differences in emotional processing (e.g., Gutchess et al., 2018; Ko et al., 2011; Masuda et al., 2008), more research would be necessary to investigate the effects of age. For instance, emotional processing in memory may be related to one's motivational goals (e.g., socioemotional selectivity theory: Carstensen, 1992), such that older adults who may perceive time as more limited relative to younger adults preferentially process and recall emotionally positive events over emotionally negative ones, sometimes called a "positivity effect", in order to pursue their emotional well-being (Mather & Carstensen, 2005). Is this tendency universal or does it differ depending on one's environment? There have been a few studies on this question, but mixed results exist even within the same cultural group (i.e., East Asia). For instance, the positivity effect was found in Koreans (Kwon et al., 2009) and Mainland Chinese (Chung & Lin, 2012; Wang et al., 2015), whereas it was not observed in Hong Kong Chinese (Fung et al., 2008). Some recent findings (e.g., Fung et al., 2019) attempted to resolve these inconsistencies, but further research is necessary to reveal in which contexts and in whom the positivity effect can be observed with age. The positivity effect is just one emotion-relevant topic, and there are, of course, many topics, such as emotion regulation or empathy, that are ripe for investigation. Understanding the joint effects of age and culture on emotional processes would be imperative to examine given the implications for well-being and the potential contribution to boosting the effectiveness of interventions (e.g., framing of messages for health behavior change).

Lastly, it is possible that some of the age effects reviewed here and used to test the model actually reflect generation or cohort effects. For example, studies in which no cultural differences were found for younger adults, but cultural differences emerged for older adults (e.g., Yoon et al., 2000; Zhang et al., 2020) might reflect differences in beliefs, attitudes, and values between younger and older adults in East Asia due to globalization and westernization in younger generations. These concerns can be mitigated using longitudinal study designs as well as by studying multiple cohorts (e.g., comparing Koreans currently living in Korea to those who immigrated from Korea to the US to Americans currently living in the US).

Conclusions

Despite the limitations and need for further research, this manuscript examined the joint effects of age and culture on cognitive processes. Our perspective is novel in calling for a lifespan perspective and serving as the first attempt to jointly review literature on cultural differences in child and adult development, integrating both lines of research into a model. The current paper advances understanding of cognitive aging by: First, accounting for culture – as an individual difference factor and as an experiential factor – allows us to test assumptions of generalizability and to delineate patterns of biological aging – thought to be consistent across cultures – from culture-specific experiential influences on aging. Second, framing the study of cultural differences within a lifespan perspective allows us to gain more insight into the critical mechanisms that can explain cognitive development with a continuous approach across life stages.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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IC: conceptualization, visualization, writing – original draft, review and editing.

AG: conceptualization, funding acquisition, visualization, writing – review and editing.

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Data availability

No data was used for the research described in the article.

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