Neurocognitive Processes for Uncertainty Processing: Adult Age Differences in Decision Making and Action Perception

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Abstract

Adaptive cognition under uncertainty depends on the ability to identify which information is relevant, reliable and useful for guiding behavior. This dissertation investigates the neurocognitive processes that support information processing under uncertainty and examines how these processes change with aging. Across three empirical studies comprising four experiments, uncertainty was examined in two functional domains: value-based decision making and action perception. In the first domain, this research focused on adult age differences in behavioral and neural responses reflecting individuals' sensitivity to whether new observations provide information that can or cannot reduce uncertainty about future outcomes. In the second domain, the experiments in Study III investigated how uncertainty in sensory inputs influences younger and older adults in the hierarchical processing of sensory, action-related, and social-communicative information when perceiving others' actions.

Studies I and II used a modified gamble bidding task combined with functional near-infrared spectroscopy (fNIRS) and a Bayesian normative model to dissociate belief updating, value updating, and expectancy violation under conditions with reducible and irreducible uncertainty. Study I showed that younger adults updated subjective values selectively when new information reduced uncertainty about winning probabilities, indicating sensitivity to the nature of uncertainty in the decision context. Moreover, their updating was valence-dependent: information indicating a decrease in winning probability was integrated more closely in line with Bayesian predictions, whereas information indicating an increase in winning probability was underweighted relative to the normative perspective. In line with previous findings, frontoparietal brain regions were involved in the different components of updating. Study II extended the same paradigm to older adults and revealed partial preservation but reduced sensitivity to uncertainty reduction in old age. Older adults updated values when uncertainty could be reduced but also showed non-normative updating even when new information was not statistically informative or relevant. Furthermore, their updating behavior was driven more strongly by expectancy violation than by belief. The observed overlapping frontoparietal activity patterns for belief updating and expectancy violation suggested reduced neural distinctiveness of these subprocesses in older adults.

Study III examined sensory uncertainty during action perception by combining behavioral similarity judgments (Experiment 1) with analyses of time-resolved and source-estimated brain activity measured with magnetoencephalography (MEG, Experiment 2) within a multivariate representational framework. In both younger and older adults, affective-communicative features uniquely accounted for larger amounts of variance in similarity judgments (Experiment 1) than visual and action-related features. During action observation in Experiment 2, sensory uncertainty was increased through stimulus blurring in one condition. Participants viewed the same action stimuli in their original form or in a Gaussian-blurred version that reduced fine-grained visual detail while preserving the overall spatial layout and structure. In both younger and older adults, neural processes followed a temporal hierarchy from visual to action-related and affective-communicative features. However, relative to younger adults, in older adults, visual feature processing was delayed while affective-communicative processing emerged earlier. Furthermore, during situations with increased sensory uncertainty, this prioritization in older adults became even more pronounced. Specifically, older adults processed affective-communicative features before action-related features, whereas younger adults preserved the original hierarchy even with increased sensory uncertainty.

Together, these findings reveal age-related differences in neurocognitive processes in uncertainty processing across two functional domains. In decision making, increased reliance on expectancy violations may impair updating when such signals are not informative. In action perception, prioritizing socially meaningful information may guide perception when sensory input is degraded. This dissertation advances a process-based account of neurocognitive aging, suggesting that normal aging cannot be characterized as uniform decline, but rather as context-dependent changes in how information is processed, weighted, and temporally organized in response to uncertainty in the task contexts or sensory signals.