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COMMENTARY

Lifespan development of neuromodulation of adaptive control and motivation as an ontogenetic mechanism for developmental niche construction

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This is a commentary on Flynn *et al.* (2012).

In evolutionary biology, the niche construction theory of Laland and colleagues (Laland, Odling-Smee & Feldman, 1999) postulates that the organism's activities could result in substantial modifications to the environment. Moreover, environmental modifications and their effects may persist over long periods, constituting the so-called 'ecological inheritance' for future generations. As such, the organism-initiated niche construction process is also a casual mechanism for evolutionary change, and not just an outcome. The target article by Flynn, Laland, Kendal and Kendal (2012) extends the original theory by zooming in on ontogeny to highlight that: developmental processes constitute key intermediate mechanisms that channel bi-directional interactive processes between gene-based and culture-based niche construction (see Figure 1 in the target article). From the perspective of a lifespan researcher interested in biocultural co-constructive dynamics between environmental and neurobiological processes of development, Flynn *et al.*'s developmental focus on niche construction is much appreciated.

Instead of viewing organisms and individuals as passive recipients of their biological, ecological, and cultural inheritances, the developmental niche construction theory and the biocultural co-construction framework both emphasize that the individual's agency plays a key role in regulating how environmental and sociocontextual influences may affect the course of ontogeny. Indeed, in the target article, Flynn *et al.* state that 'infants and children both being directed, and directing, their own environment'. In our own work on biocultural co-construction of developmental plasticity (Baltes, Reuter-Lorenz & Rösler., 2006; Li, 2003; cf. Gottlieb, 1998), it is underscored that individuals are not merely passive receivers of their biological and cultural inheritances; rather, individuals are active agents who make choices and take actions to regulate the available resources for promoting their own development (Li & Freund, 2005; cf. Baltes & Baltes, 1990; Ford, 1987; Freund, 2008).

If individual agency is the active driver of developmental niche construction, then psychological and neurobiological mechanisms of adaptive cognitive control and motivation underlie the development of individual agency. In this commentary, I thus hope to add some specificity to one type of ontogenetic mechanism that is relevant for developmental niche construction. Specifically, I focus on the maturation and senescence of neurotransmitter systems, which play crucial roles in the development of executive control, motivation, and the regulation of reactions to social and environmental stressors.

To better capture the cross-level interactive dynamics of development, a perhaps fruitful conceptualization is to view lifespan development as the development of adaptive neurocognitive representations that are 'embodied' in motor, sensory, and perceptual processes and 'situated' in social and environmental contexts (see Clark, 2001). As self-organizing systems, brains optimize the levels of matches and mismatches between environmental states and action outcomes (Friston, 2010). The embodied and situated neurocognitive representations are modulated by various neurotransmitters that implicate executive control, working memory, and motivational processes (see Cools & D'Esposito, 2011; Cools, Roberts & Robins, 2008, for reviews; see Figure 1A for a

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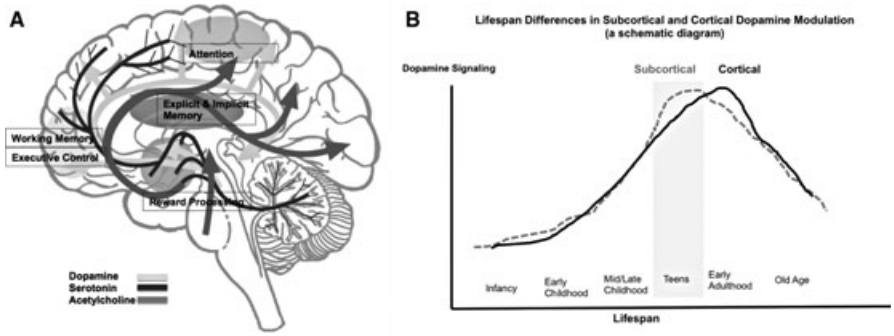

Figure 1 (A) Schematic diagram of major transmitter pathways, subserving adaptive cognitive control, memory, and motivation processes. (B) Schematic diagrams of the trajectories of the subcortical and cortical dopamine systems across the lifespan (adapted from Li, 2012, *Developmental Psychology*, copyright American Psychological Association).

schematic diagram). Indeed, neuromodulatory systems have been considered as key neural substrates for adaptive value-dependent selection in the brain (Friston, Tononi, Reeke, Sporns & Edelman, 1994). Depending on situational demands and the integrity of brain functions, neurotransmitters modulate task-relevant brain circuitries, so that individuals can adapt their behavior, action, and goals. Therefore, the maturation (e.g. Diamond, Briand, Fossella & Gehlbach, 2004; Tunbridge, Weickert, Kleinman, German, Chen, Kolachana, Harrison & Weinberger, 2007) and senescence (see Figure 1B for a schematic diagram; see Bäckman, Nyberg, Lindenberger, Li & Farde, 2006; Li, 2012, for reviews) of neurotransmitter systems have direct implications for lifespan development of adaptive cognitive control and working memory (e.g. Diamond *et al.*, 2004; Nagel, Chicherio, Li, von Oertzen, Sander, Villringer, Heekeren, Bäckman & Lindenberger, 2008; Störmer, Passow, Biesenack & Li, 2012), reward and motivational processes (see Eppinger, Hämmerer & Li, 2011; Li, 2012, for reviewa) as well as reactions to other factors in the developmental context, such as environmental or social stress (e.g. Armbruster, Mueller, Strobel, Lesch, Brocke & Kirschbaum, 2011; Plessow, Fischer, Kirschbaum & Goschke, 2011).

In conclusion, the degree of matches and mismatches between the environmental states and the current action goals may motivate humans to indeed engage themselves in modifying their own developmental niche. Brain mechanisms for adaptive control and motivation are finely tuned by various transmitter systems that undergo maturation and senesce across the lifespan.

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