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## Characterization and intervention for upper extremity exploration & reaching behaviors in infancy

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### ABSTRACT

This article aims to: 1) highlight general exploration, reaching, and object exploration behaviors as key activities of daily living in infancy, 2) describe how knowledge of early warning signs for these behaviors may improve early assessment, and 3) discuss interventions that may advance performance of these behaviors. Early intervention should focus on improving performance of these behaviors because: a) these early, interrelated upper extremity behaviors serve an integral role in global learning and development in infancy, b) among at-risk populations, differences have been observed in the quantity and quality of performance of these behaviors and, in many cases, these differences are associated with related perceptual-motor and cognitive delays. This article highlights how early assessment and intervention can target these key early behaviors in populations at risk for upper extremity disabilities, such as those born preterm, with Down syndrome, brachial plexus palsy, or arthrogryposis multiplex congenita.

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### Introduction

The purpose of this article is to summarize the research related to three key categories of early upper extremity behaviors: general exploration, reaching and object exploration behaviors. Specifically, we focus on 1) how these behaviors differ between infants who are typically developing and infants 'at risk' for long-term impairments and functional limitations, and 2) interventions that may be used to improve early performance of these behaviors.

The first year of life is a time of significant exploration, learning, and change, and the upper extremities can serve as important tools in these processes.<sup>1–3</sup> Together, general exploration, reaching and object exploration behaviors, allow curious and motivated infants to explore, gather information, and learn about their bodies, objects, and the complex relationships between them.<sup>4,5</sup> We chose to

highlight these behaviors because they are key activities of daily living for infants, are developmentally interrelated, and are important precursors for *future* activities of daily living including feeding, dressing, and academic activity. These behaviors are especially relevant to clinicians and families as they present differently in infants at risk, impact learning and development, and offer opportunities for targeted intervention strategies.<sup>6,7</sup> Therefore, early intervention providers and medical professionals should be focused on these 'high impact' behaviors for early identification and treatment of delays.<sup>8–10</sup> We begin this article by defining each of these categories of behaviors, briefly describing their typical development, and highlighting their interrelatedness.

#### General exploration behaviors

*General exploration behaviors* are the seemingly random movements infants engage in with their upper extremities when they are interacting with their bodies and surfaces around them.<sup>11</sup> Embryos begin performing these behaviors around 8 weeks in utero.<sup>12</sup> A variety of terms have been used to label these behaviors. For instance, these behaviors have been termed spontaneous movements because they seem not to be elicited by external triggers.<sup>13</sup> A subset of these behaviors involving waving or flapping of the arms

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has also been referred to as pre-reaching behaviors, although these waving behaviors continue even after reaching has emerged.<sup>14</sup> Because infants perform a variety of behaviors with their upper extremities when objects are not present, including feeling their body and surfaces, mouthing their hands, waving their arms, and looking at their hands, we refer to these behaviors here as general exploration behaviors because they provide opportunities for infants to gather information to learn about their own bodies and surfaces around them.<sup>15,16</sup>

### *Reaching behaviors*

*Reaching behaviors* bring one's hand to a target.<sup>17</sup> Reaching for objects with the arms typically emerges between 3 and 5 months of age.<sup>18</sup> Younger infants demonstrate reaching with their hands for parts of their bodies, such as their mouths or faces.<sup>19</sup> They also commonly show the drive and ability to attain objects by reaching using other parts of their bodies such as their mouths or feet.<sup>20</sup>

Reaching behaviors and general exploration behaviors are developmentally interrelated. The ability to reach dynamically emerges from the general exploration behaviors infants learn to perform each day.<sup>18</sup> For instance, even before infants can successfully reach, they alter their general arm movements when objects are presented within reach.<sup>21</sup> For example, in the month or two before infants reach for and contact toys, they adapt their general arm movements to become faster, smoother, and closer to toys when they are present versus without toys in view. In addition, infants learn in an individualized manner how to successfully adapt their general arm movements to contact an object without over- or under-shooting the target. Infants with slower general arm movements learn to ramp up their speed to reach a target while those with faster general movements learn to dampen their movement speed to accurately reach targets.<sup>18</sup> Furthermore, infants' ability to perform general exploration behaviors in midline predicts the onset of successful reaching for objects.<sup>20</sup> Thus, everyday general movement behaviors serve as the behavioral repertoire from which reaching behaviors emerge.

### *Object exploration behaviors*

*Object exploration behaviors* provide infants opportunities to gather information about the properties of objects.<sup>22</sup> These behaviors include exploring objects with the mouth, looking at objects, and rotating and fingering objects to visually and haptically explore the surfaces of objects.<sup>23</sup> Humans begin performing some of these behaviors in utero or within the first months of life.<sup>24,25</sup> When infants gather information about objects via exploratory behaviors they learn about causal relationships and about the affordances of objects, or how they can interact with them.<sup>26,27</sup>

Object exploration behaviors also closely relate to the general exploration and reaching behaviors infants perform. For instance, when provided with objects for the first time, young infants do not immediately perform new behaviors but rather interact with those objects by amplifying and combining already existing general exploration behaviors they perform daily to explore their own bodies and surfaces.<sup>16</sup> Therefore, like reaching, object exploration behaviors emerge dynamically from infants' ongoing general exploration behaviors.<sup>28</sup>

Reaching experience also impacts the behaviors infants use to explore objects. For example, when objects are attached to infants' hands using hook and loop material, infants mouth, look at, and finger the objects more after they have been classified as reachers than before, despite the fact they were able to perform these behaviors across all assessment points.<sup>16</sup> In addition, infants who reach earlier and have more advanced exploratory abilities also have better

performance when attempting causal learning tasks that involve object exploration such as using a switch to control a device.<sup>29</sup>

Thus, these three behavioral categories, general exploration, reaching, and object exploration, can be viewed as a developmental continuum whereby the development of the latter behaviors is influenced by the development of the earlier behaviors.<sup>28</sup> This is a critically important concept for therapists because it suggests that early delays in these behaviors are likely to persist and amplify. Conversely, early interventions targeting one or more of these behaviors are likely to positively impact performance of the other behaviors and global learning and development as well.<sup>16,29</sup>

Having provided definitions and evidence of behavioral interrelatedness, we will next review the general exploration, reaching, and object exploration literature for infants at risk to highlight differences from typical development in performance quality and quantity, how these differences relate to other areas of development and learning, and ways knowledge of these differences can inform our early assessments. We then review the literature to describe interventions that can potentially improve performance of these three key types of behaviors. We focus throughout on four populations of infants at risk for upper extremity disabilities: infants born preterm, with Down syndrome (DS), with brachial plexus palsy (BPP), or with arthrogryposis multiplex congenita (AMC). As we review the findings from the literature pertaining to these diagnoses, note that the amount of literature on early upper extremity development and intervention is more limited for infants with BPP and AMC.

## **Characteristics of upper extremity behaviors among infants at risk for upper extremity disabilities**

In reporting the atypical characteristics of upper extremity behavioral development often observed for infants at risk, we group the information to follow by behavioral characteristic rather than by diagnosis or risk factor of the child. This method of organization was chosen because the current literature suggests many of these atypical characteristics present across populations.<sup>6,7</sup> With further study, it is likely even more commonalities will be revealed in these atypical characteristics across at-risk populations.

### *General exploration behaviors*

Early identification of motor and associated cognitive disabilities is especially challenging in the first year of life. Assessment of general exploration behaviors is worthwhile for the potential identification of very early differences in infants' movement and information gathering techniques that can persist and broadly impact development (Table 1). Several key differences exist in the performance of general exploration behaviors for populations of infants at risk. Moreover, these differences may predict the presence of future neuromotor impairments and developmental delays (Table 1).<sup>12,30–32</sup> For example, compared to preterm infants with low risk, infants born preterm with high risk, due to low gestational age, low birth weight, and/or low Apgar scores, have general exploration behaviors at one month corrected age characterized by more monotony, less variability, and less complexity.<sup>33</sup> Preterm infants with poorer general exploration behaviors are more likely to have poorer cognitive development and eye-hand coordination at two years.<sup>30</sup>

Assessment of general movements in the first four months of corrected age using Prechtl's published methods<sup>34,35</sup> has been shown to be highly sensitive and specific (71–100% and 86–97% respectively with best results at 3 months corrected age) for predicting the future development of cerebral palsy and neuromotor

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