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# Developmentally informed behaviour change techniques to enhance self-regulation in a health promotion context: a conceptual review

Alison L. Miller<sup>a</sup>, Sharon L. Lo<sup>a</sup>, Katherine W. Bauer<sup>b</sup> and Emily M. Fredericks<sup>c</sup>

<sup>a</sup>Department of Health Behaviour and Health Education, School of Public Health, University of Michigan, Ann Arbor, MI, USA; <sup>b</sup>Department of Nutritional Sciences, School of Public Health, University of Michigan, Ann Arbor, MI, USA;

<sup>c</sup>Department of Pediatrics, University of Michigan School of Medicine, Ann Arbor, MI, USA

## ABSTRACT

Self-regulation (SR), or the ability to manage thoughts, emotions, and behaviours in order to achieve a desired goal, is seen as underlying positive health behaviours. In adults, behaviour change techniques (BCTs) are recommended to promote SR across health domains; although establishing healthy habits early in life is important, studies of SR and health in children are rare. This conceptual review provides guidance on developmental considerations for applying BCTs to enhance SR capacity in children and youth with the goal of fostering positive behavioural health trajectories early in the lifespan. Key considerations include the nature of developmental changes in SR and interaction among SR processes; temporal associations between SR and health behaviours; and relevance of health goals for children and youth. Building on a meta-review of BCTs used to promote SR in adults and youth, this conceptual review highlights key SR milestones to consider in behaviour change-focused interventions from early childhood through adolescence and provides an overview of social-ecologic influences on SR development and associations between SR and health behaviours across these age periods. Implications for and examples of using developmentally-informed BCTs in interventions to enhance SR in children and youth are noted and suggestions for future research are discussed.

## ARTICLE HISTORY

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## KEYWORDS

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intervention; behaviour  
change techniques (BCTs)

Self-regulation (SR) – broadly defined as managing thoughts, emotions, and behaviours in order to achieve a desired goal – is thought to be a central mechanism underlying health behaviours (Eisenberg et al., 2019; Miller, Gearhardt, et al., 2018). Although many health problems facing the modern world have broad social and contextual roots, individual factors such as SR are hypothesised to modulate the extent to which environmental factors translate into health behaviours (Blair, 2017; Nielsen et al., 2018). Individual differences in SR can foster resilience, such that some individuals engage in and maintain healthy behaviours in the face of stressors, whereas others do not (Hagger et al., 2019). Thus, SR may be a mechanism in the pathway to behaviour change in the context of daily challenges to healthy behaviour. As SR can be malleable (Pandey et al., 2018) and prevention of disease is typically more effective than treatment, SR-focused interventions early in life offer promise for fostering positive behavioural health trajectories. Yet, health behaviour studies rarely directly address SR in children and youth.

Behaviour change techniques (BCTs) such as self-monitoring and action planning have been suggested to promote SR in adults (Michie et al., 2013). Few studies have explicitly considered the

use of BCTs among children or youth. For example, in a recent meta-review of 66 meta-analyses that used BCTs to promote SR in health behaviour change interventions (Hennessy, Johnson, Acabchuk, McCloskey, & Stewart-James, 2019), only 5 meta-analyses included children. Yet, two of these highlighted developmental differences in effectiveness of SR-related BCTs in promoting health behaviours, suggesting that a developmental perspective is important in using BCTs to promote SR and health behaviours in children and youth. Identifying BCTs to promote SR in children and youth is challenging due to the dramatic changes in SR capacities and the many influences on SR across development. SR develops rapidly during the first years of life, aspects of SR interact and develop at different rates, and SR typically becomes more stable through adulthood (Sameroff, 2010). The goal of this conceptual review is to raise awareness of developmental factors that are important for investigators and interventionists alike to consider when tailoring BCTs to enhance SR with the goal of health promotion across different developmental periods. As such, we review developmental milestones in SR, influences on SR, and SR-health behaviour associations from early childhood to adolescence. We also provide examples of developmentally-informed applications of using BCTs to enhance SR across different developmental periods (Table 1).

### **Developmental considerations regarding behaviour change techniques and self-regulation**

BCTs have been proposed as a way to promote SR and thus sustained health behaviour change (e.g., diet, physical activity, substance use, chronic illness management) (Hagger et al., 2019). The recent meta-review suggested that certain BCTs, specifically goal setting, prompt self-monitoring, and identification of barriers and problem-solving, may be particularly important for promoting SR (Hennessy et al., 2019). Health behaviour interventions often use such BCTs to promote SR in order to link intentions to health behaviours, as intentions do not always translate into actions. For example, although an individual may intend to eat salad and exercise after work, barriers such as stress, desire for sedentary activity, or food cravings can get in the way. This process has been described as a tension between ‘wants’ and ‘shoulds’ (Duckworth, Milkman, & Laibson, 2018), and may be thought of as a conflict between primarily bottom-up, reactive processes such as impulsivity, versus more top-down, deliberate processes such as planning (Jonas & Kochanska, 2018; Nigg, 2017). Reactive processes are quick, often emotional or impulsive responses to stimuli, whereas top-down processes involve slower, typically more complex, effortful, or intentional responses that can function to reframe or modulate initial response. SR-related challenges to health behaviour change often emerge as a result of these two systems being ‘imbalanced.’ Although such dual-process framing is oversimplified, as these processes can interact and influence each other in a bidirectional manner, this framework is adopted to highlight these different processes as related to SR.

In order to develop effective BCTs to promote SR across the lifespan, it is first important to understand developmental aspects of SR that have implications for health behaviour. There is a vast literature on SR development, and recent reviews in developmental science (Bailey & Jones, 2019; Jonas & Kochanska, 2018; Nigg, 2017) and basic psychological sciences (Eisenberg et al., 2019) have therefore sought to integrate different research traditions. Untangling the multitude of terms used in SR research (e.g., hot vs. cool executive functioning, effortful control, attentional control) is beyond the scope of the present review. Yet, it is worth noting that continued debate about SR conceptualisation, terminology, and measurement in children limits to some degree the extent to which researchers can elucidate typical SR developmental trajectories, and which aspects of SR may be most responsive to specific BCTs.

### **Self-regulation, BCTs, and health behaviour in children: intervention implications**

Central developmental considerations regarding using BCTs to promote SR in children and youth include the nature of developmental change in SR processes, individual differences and social-

**Table 1.** Developmentally-Informed Applications of Behavior Change Techniques (BCTs) for SR Promotion.

Developmental Period	Child Age	Social Context	Sample BCTs	Examples of Developmentally-Informed BCTs in Practice	Sample Child SR Targets
Infancy and Toddlerhood	Under 3 years	Parents / Caregivers	<ul style="list-style-type: none"> <li>Stress management</li> <li>Time management</li> <li>Goal setting</li> </ul>	Parent-directed BCTs can help parents scaffold infant SR by supporting parent's own SR capacity for responsive caregiving (e.g., improving stress management), or by using time management and goal setting BCTs with parents to establish consistent routines at home (bedtime, mealtimes)	<ul style="list-style-type: none"> <li>Attention shifting</li> <li>Soothability</li> <li>Rhythmicity</li> </ul>
Early Childhood	3–5 years	Parents / Caregivers Classroom Peers	<ul style="list-style-type: none"> <li>Stress management</li> <li>Self-talk (e.g., labelling emotions)</li> <li>Barrier identification</li> <li>Distraction<sup>†</sup></li> <li>Demonstration of behaviour<sup>†</sup></li> <li>Social rewards<sup>†</sup></li> <li>Reattribution<sup>†</sup></li> <li>Information about social consequences<sup>†</sup></li> <li>Restructuring environment<sup>†</sup></li> </ul>	Child-directed individual BCTs such as stress management (e.g., teaching relaxation strategies) and simple self-talk and reattribution (e.g., using words to express emotions or focus on non-rewarding properties of desired object) can promote SR; peer- and classroom-directed BCTs may include identifying barriers in the environment to increase structure; modelling by peers and adults; social rewards; and natural consequences of peer conflicts	<ul style="list-style-type: none"> <li>Attention shifting</li> <li>Self-soothing</li> <li>Emotion knowledge and understanding</li> <li>Impulse control</li> <li>Mindfulness</li> </ul>
Middle Childhood	6–10 years	Parents Classroom Peers Self/ Individual	<ul style="list-style-type: none"> <li>Stress management</li> <li>Prompting self-monitoring</li> <li>Prompting self-talk</li> <li>Personalised feedback</li> <li>Social comparison<sup>†</sup></li> <li>Reattribution<sup>†</sup></li> <li>Identity<sup>†</sup></li> <li>Information about social consequences<sup>†</sup></li> </ul>	Child-directed BCTs can involve increasingly complex stress management and reattribution strategies (e.g., distancing, reappraisal) to enhance emotional control and flexibility, as well as self-monitoring and self-talk to enhance top-down SR (e.g., planning skills); BCTs involving social consequences, comparison to peers and personalised feedback can also become important with rapid self-concept and identity development across this phase	<ul style="list-style-type: none"> <li>Attention shifting</li> <li>Emotional control</li> <li>Mindfulness</li> <li>Cognitive flexibility and planning</li> <li>Social perspective taking</li> <li>Metacognition</li> </ul>
Early to Later Adolescence	11–18 years	Parents Classroom Peers Self/ Individual	<ul style="list-style-type: none"> <li>Stress management</li> <li>Prompting self-monitoring</li> <li>Prompting self-talk</li> <li>Personalised feedback</li> <li>Action planning</li> <li>Relapse prevention/coping planning</li> <li>Goal setting</li> <li>Problem solving</li> <li>Social comparison<sup>†</sup></li> <li>Identity<sup>†</sup></li> </ul>	Adolescents' increased metacognitive skills such as capacity for self-reflection can allow for more robust BCTs that are self-related (e.g., self-monitoring, goal-setting, problem-solving); increased reward sensitivity at this age may enhance response to BCTs that engage reward systems (e.g., rewarding alternative behaviour; social incentives); BCTs related to social comparison and identity become increasingly relevant as influence of peers is most salient during this period; BCTs	<ul style="list-style-type: none"> <li>Attention shifting</li> <li>Emotional and cognitive flexibility</li> <li>Social perspective taking</li> <li>Impulse control</li> <li>Mindfulness</li> <li>Future orientation</li> <li>Delay discounting</li> <li>Self-affirmation</li> <li>Self-efficacy</li> </ul>

(Continued)

Table 1. Continued.

Developmental Period	Child Age	Social Context	Sample BCTs	Examples of Developmentally-Informed BCTs in Practice	Sample Child SR Targets
			<ul style="list-style-type: none"><li>• Information about social consequences<sup>†</sup></li><li>• Rewarding alternative behaviour<sup>†</sup></li><li>• Social incentives<sup>†</sup></li><li>• Comparative imagining of future outcomes<sup>†</sup></li></ul>	that provide information about broader social consequences may also be effective as the adolescent engages with the larger social world	

Note. Sample BCTs listed include those reviewed by Hennessy et al. (2019) and in Michie et al. (2013); <sup>†</sup>indicates BCTs from Michie’s taxonomy.

contextual influences on SR, temporal aspects of SR and behaviour change, and relevance of health goals. These considerations are each briefly reviewed below, followed by in-depth illustrations of SR developmental milestones, key influences, and findings linking SR to health across developmental stages from infancy to adolescence.

Regarding the nature of developmental change, SR processes follow a nonlinear course such that behavioural control emerges relatively rapidly, whereas cognitive control processes emerge slowly and steadily over time (illustrated in Figure 1). Thus, management of bottom-up impulses is a primary feature of SR development during the early years, and top-down cognitive control capacities become more finely-tuned across adolescence and early adulthood. Development is also hierarchically organised such that foundational aspects of SR, including rudimentary working memory, basic attention skills, and impulse control develop early in the lifespan (Diamond, 2013; Marcovitch & Zelazo, 2009) and become more automatic, less effortful, and more closely integrated and coordinated across development.

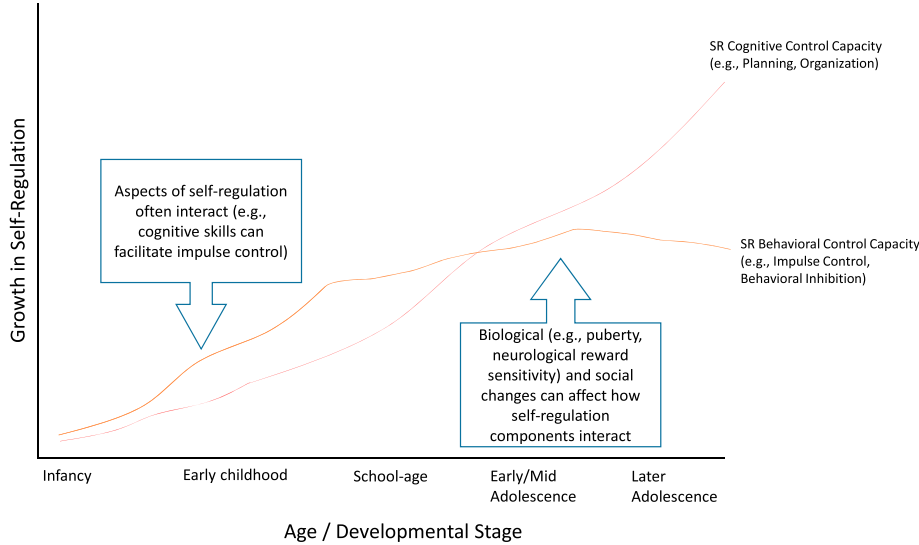


Figure 1. Growth in different aspects of self-regulation (SR) in children and youth.

Note. SR development is not linear. Aspects of SR develop at different rates and are shaped by different influences (e.g., individual differences in biology, personality, and experience).

Regarding individual differences, temperamental factors such as reward sensitivity, which can be defined as an individual's propensity to detect, enjoy, and seek out positive stimulation, can shape SR capacity. For example, young children who are highly reward sensitive may have more difficulty with SR than others when waiting for a treat. Reward sensitivity is also differentially salient across development and peaks in adolescence, thus can be a key influence on SR at this period (Somerville, Jones, & Casey, 2010). Understanding SR capacity of the focal population, and the environmental influences on SR across development, is critical in order to create developmentally-sensitive interventions that include BCTs. Table 1 illustrates social contexts that help shape SR (e.g., parents; peers) and in which BCTs may be delivered to enhance SR at different points in development.

Temporal aspects of SR also have implications for BCTs. For example, a developmental perspective is essential when considering use of BCTs that involve scheduled consequences and rewards or imagining future outcomes (Michie et al., 2013) because concepts of time emerge with development. For young children, the future is relatively immediate, whereas older children and adolescents are progressively able to imagine longer time horizons (McCormack & Hoerl, 2008). Thus, phrases such as 'eating vegetables will make you grow big and strong' (future-oriented, vague) versus 'eating vegetables will give you energy to run in the playground' (immediate, concrete) may differ in terms of their likelihood to motivate behaviour change at different ages. Understanding how children perceive different timescales could result in more effective BCTs that tailor time-sensitive strategies in a developmentally-appropriate manner.

Finally, and perhaps most critically when considering SR in relation to health promotion, most children and youth do not have articulated health or behaviour change goals. Thus, using BCTs like strengthening commitment to a health goal in order to promote future health or avoid future health problems may not be salient for most children unless they have a health concern or condition. Among youth with a chronic illness, better SR is associated with better illness self-management and regimen adherence; thus BCTs to improve SR may be particularly important for children with identified health goals (Lansing & Berg, 2014; Schwartz & Drotar, 2006).

### ***Infancy and Toddlerhood (under 3 years)***

#### ***SR milestones***

Individual differences in processes such as focused attention, rhythmicity, and soothability are present from birth (Rothbart, Sheese, Rueda, & Posner, 2011). The attentional networks, or neural systems responsible for alerting and orienting an individual to stimuli, are thought to drive SR capacity in this early stage. Across the first year of life, children rapidly increase in their ability to self-soothe (Bell & Wolfe, 2004) and show early working memory skills such as searching for an object after a delay (Marcovitch & Zelazo, 2009). By the end of the second year of life, children can more reliably wait for a desired gift and show some capacity to inhibit behavioural impulses (Carlson, 2005). Simpler skills like working memory develop earlier than more complex skills like cognitive flexibility (Diamond, 2013; Rothbart et al., 2011). The timescale for SR during the first 3 years is also quite short – children this age can tolerate brief delays, but should not be expected to wait for longer than a few minutes without some external distraction (e.g., toys). Furthermore, it is often difficult for toddler-aged children to demonstrate SR under challenging conditions.

#### ***Influences on SR***

Individual SR capacity emerges through a process of coregulation with a caregiver; thus, any BCTs to promote SR during this phase of development must operate through caregiving relationships. Although the infant or young child contributes to the early caregiving relationship (Bell & Wolfe, 2004; Sameroff, 2010), caregivers have primary responsibility for scaffolding the infant's ability to regulate; for example, soothing when upset, feeding when hungry, and providing safe spaces to explore and to sleep. This relationship helps infants develop their physiological capacity to manage states of arousal, sleep, and hunger (Paul et al., 2018), and lays the groundwork for a

young child's later individual SR capacity to regulate emotions, inhibit impulses, and develop executive attention and planning skills (Bernier, Carlson, & Whipple, 2010; Rothbart et al., 2011). As children practice these skills in the context of early caregiving relationships, they learn how to self-regulate on their own in increasingly sophisticated ways.

### ***BCTs, SR and health promotion***

During infancy and early childhood, many health-focused interventions address parents' developmental expectations and routines such as regular feeding/mealtime and bedtime schedules (Paul et al., 2018). BCTs could also be used to support parents to engage in these behaviours, which can directly promote child SR through establishing consistent and structured environments and routines around health, including safety, sleep, and nutrition, and show promise for promoting healthy growth (Baker, Morawska, & Mitchell, 2019; Paul et al., 2018). Yet, such interventions do not typically consider how to support the SR capacity of caregivers to serve as responsive, external 'regulators' for the child during infancy. Given known intergenerational transmission of SR (Bridgett, Burt, Edwards, & Deater-Deckard, 2015) and increased recognition of how stress can reduce parents' own SR capacity, it is essential to address parents' SR needs during the early parenting years (Crandall, Deater-Deckard, & Riley, 2015; Miller, Miller, & Clark, 2018). Thus, beyond promoting consistent sleep and feeding routines to directly support infant SR development, using BCTs to support parents' own SR capacity may be an important, yet unexplored indirect way to enhance child SR at this age through promoting capacity for positive and consistent parenting (see Table 1).

### ***Early childhood (3 – 5 years)***

#### ***SR milestones***

Dramatic SR gains are seen in early childhood (Diamond, 2013; Marcovitch & Zelazo, 2009). Children can increasingly control impulses, wait longer for desired items, and follow simple instructions (Carlson, 2005; Montroy, Bowles, Skibbe, McClelland, & Morrison, 2016). They can actively engage SR strategies to increase attentional focus and regulate emotions when upset (Blair, 2017). Emerging language and perspective-taking skills can also enhance the capacity of preschool-aged children to set-shift, or switch attentional focus in order to generate new solutions (Montroy et al., 2016). Such skills help them engage the 'building blocks' of emotion regulation, for example identifying and labelling emotions in themselves and others that allow coping under challenging conditions (Cole, Dennis, Smith-Simon, & Cohen, 2009). Indeed, SR skills become critical for children to manage their own emotions and behaviours and maintain social interactions with their peers.

#### ***Influences on SR***

Parents remain a major influence on SR throughout the preschool years, and as noted above, parents' own SR capacity can shape child SR through management of the home environment, modelling, and provision of opportunities to practice skills (Baker et al., 2019; Bridgett et al., 2015; Crandall et al., 2015). Recent work has applied BCTs with parents to promote specific behaviours at this age, for example book reading (Mayer, Kalil, Oreopoulos, & Gallegos, 2019), but this has not been attempted for general SR or health-focused outcomes. Peers also become influential in preschool. Interacting with partners with inconsistent SR may even afford important practice opportunities that may not arise when practicing in a more scaffolded manner with a parent or teacher (Durbin, 2018). For example, children can enact SR 'in vivo' when engaging with peers (e.g., during conflicts). Peers' SR capacities can shape children's SR, specifically effortful control across the course of a preschool year (Neal, Durbin, Gornik, & Lo, 2017), and children in classrooms with more free choice, compared with teacher-led instruction, showed greater gains in inhibitory control skills (Goble & Pianta, 2017).



### *BCTs, SR and health promotion*

Child-focused individual BCT strategies involving reattribution (e.g., pretending marshmallows are fluffy clouds in a delay of gratification task) may help promote SR skills such as inhibition at this age (Mischel & Ayduk, 2002). Yet, given the salience of the preschool peer context, many SR-focused interventions use socially-oriented BCTs such as restructuring the preschool environment (Blair & Raver, 2014; Raver et al., 2011; Tominey & McClelland, 2011). Peer-context interventions, meaning interventions that take place in a classroom or other peer group setting, have used activities such as mindfulness (Poehlmann-Tynan et al., 2016), yoga (Razza, Bergen-Cico, & Raymond, 2015), physical activity (Becker, McClelland, Loprinzi, & Trost, 2014), and motor competence (Robinson, Palmer, & Bub, 2016) to successfully promote SR. Observational studies have identified associations among individual SR skills and health outcomes, primarily obesity, during early childhood (Caleza, Yañez-Vico, Mendoza, & Iglesias-Linares, 2016). Yet, interventions that have tested whether improving SR reduces obesity risk have found mixed support (Brotman et al., 2012; Lumeng et al., 2017). Unpacking the mechanisms through which early SR relates to different health behaviours both concurrently and longitudinally is essential as the impact of early SR interventions on health may emerge over time (Baker et al., 2019; Epstein & Anzman-Frasca, 2017). Preschool classrooms are a common setting for health-focused programmes that entail education or peer modelling of specific health behaviours (e.g., tasting vegetables), yet with varying results (Nekitsing, Blundell-Birtill, Cockroft, & Hetherington, 2018). Using both individual and peer-oriented BCTs in classrooms to enhance SR at this age (e.g., self-talk, reattribution, social rewards, restructuring the environment; see Table 1) may be a way to increase effectiveness of extant approaches.

### *Middle childhood*

#### *SR milestones*

School-aged children (~ 6–10 years) have increased capacity to manage bottom-up impulses. Although such abilities may be taxed under demanding conditions, children this age can typically resist temptation (Duckworth, Gendler, & Gross, 2014; Mischel & Ayduk, 2002) and have strategies for managing emotions when frustrated or disappointed (Zeman, Shipman, & Suveg, 2002). Children this age are also developing metacognition, a construct related to SR that includes self-awareness and self-reflective capacity (Gascoine, Higgins, & Wall, 2017). Due to their increased metacognitive capacity, school-aged children also improve their capacity for top-down SR skills such as planning and organisation. Such skills are needed for success in the school context (Best, Miller, & Naglieri, 2011), due to increased homework demands and other activities that require postponing immediate gratification in order to engage in complex tasks that require focus and attention to detail.

#### *Influences on SR*

Parents continue to model healthy behaviours, but gaining independence is a normative developmental milestone during this period and peer influence increases. Related to their increased capacity for complex cognition, childrens' self-concept becomes established at this age, and they begin to compare themselves with peers (Harter, 2006). Such skills make it possible to evaluate individual performance relative to others or to one's own prior performance (i.e., self-monitor), an important BCT (Hennessy et al., 2019). Middle childhood is also a period of change in social relationships; friendships move from primarily activity-based (i.e., we are friends because we are both playing basketball right now) to more person-based (i.e., we are friends because we have shared history, which may include a love of basketball) (Newcomb & Bagwell, 1995). Such changes shape SR indirectly, as children model the SR behaviours of peers (DelGiudice, 2018); thus BCTs involving social comparisons and consequences may become increasingly relevant (see Table 1).

### *BCTs, SR and health promotion*

Children make multiple SR-related decisions on a daily basis; BCTs that help them reflect on the consequences and success (or failure) of such decisions may enhance their metacognitive skills to inform



future choices, including health-related behaviours. Interventions to enhance SR in school-aged children have shown success using individually-focused BCTs such as self-talk and reattribution (Duckworth et al., 2014) and mindfulness training, which involves self-reflection and monitoring (Mendelson et al., 2010; Vickery & Dorjee, 2016; Zoogman, Goldberg, Hoyt, & Miller, 2015). Meta-analyses suggest such strategies may be more robust (Hennessy et al., 2019; Takacs & Kassai, 2019) compared to interventions that use inhibitory control training to increase SR capacity (Chacko et al., 2014; Murray, Theakston, & Wells, 2016). Although direct training interventions show some promise, there is limited transfer to new contexts and few have examined health outcomes. The recent meta-review by Hennessy et al. (2019) found that self-related BCTs, which require capacity for reflection on one's actions, for example self-efficacy to increase a desired behaviour or self-monitoring of behaviours, emerged as important. As skills to reflect on and monitor one's own behaviour typically emerge across middle childhood into adolescence; such self-related BCTs may become increasingly relevant. It will be essential, however, that any interventions that involve self-monitoring BCTs in relation to health outcomes in children also take care to avoid potentially harmful impacts of this type of tracking, given concerns that such activities may prompt disordered eating and weight control practices, for example (Simpson & Mazzeo, 2017).

Independent health habits that involve SR are becoming established in middle childhood. Children with chronic illnesses assume increased responsibility for SR-related health behaviours, such as remembering to bring their asthma inhalers or stocking their school diabetes kits (Schwartz & Drotar, 2006). Compared with younger children, school-aged children are generally exposed to more health-relevant SR challenges such as tempting food that is easily acquired or electronic screens that are constantly present. Yet, unlike adults, they likely have few health-related reasons or consequences to avoid them, making motivation uniquely challenging. Children this age also do not yet have the cognitive capacity to imagine long-term future events, nor how current actions may relate to future outcomes (Andreoni et al., 2019). Thus, BCTs that rely on promoting focus on the future (e.g., comparative imagining of future outcomes; (Michie et al., 2013)) may be less pertinent to this age group, but may be helpful for older children.

## **Early to later adolescence**

### **SR milestones**

Adolescence is characterised by increased capacities in cognitive complexity, and processing speed nears its peak in late adolescence. Compared with childhood, when impulse control may drive actions, adolescents' capacity to set goals, prioritise, and choose among competing options may be most critical for behaviour change (Steinbeis & Crone, 2016). Children this age can also reflect on specific occasions where SR has helped or hindered their success (Tsukayama, Duckworth, & Kim, 2013). Adolescents are able to imagine the possibilities that await them in the future, conceptualise their own unique identities (Becht et al., 2016), and — to some degree — gain appreciation that their current actions can shape their future self (Nurra & Oyserman, 2018). Yet, adolescence is also characterised by increased impulsivity, thought to arise in part due to interference from a heightened reward system (Somerville et al., 2010). Thus, adolescence is a striking period of developmental discontinuity in SR (see Figure 1). Adolescents are often seen as lacking in SR because SR related to impulse control is not enacted when it seems warranted (e.g., substance use, risky sexual behaviour, poor driving decisions). Yet, at the same time, adolescence is also increasingly recognised as a critical time for formative learning and motivation around health promotion, which can involve many top-down SR processes such as planning and problem-solving (Dahl, Allen, Wilbrecht, & Suleiman, 2018; Dorn, Hostinar, Susman, & Pervanidou, 2019; Telzer, 2016).

### **Influences on SR**

Adolescence is characterised by the powerful influence of peers, although the nature of peer influence can change. Younger adolescents (e.g., 13–15 years) may be concerned with conformity,

whereas older adolescents may move between peer groups as they ‘try out’ and consolidate identities into emerging adulthood (Kroger, Martinussen, & Marcia, 2010). Peers impact adolescents’ capacities to engage both bottom-up and top-down SR processes under emotionally challenging conditions (Pfeifer et al., 2011). Adolescents’ reward sensitivity and risk-taking behaviours have been shown to vary as a function of perceived peer presence (Cascio et al., 2015; Chein, Albert, O’Brien, Uckert, & Steinberg, 2011). Reward sensitivity may positively impact health behaviours by enhancing motivation and attention under circumstances that promote prosocial, adaptive (vs. risky) choices (Telzer, 2016). Social context is critically important; the presence of parents can reduce risk taking, and the presence of peers can enhance it (Dahl et al., 2018; Telzer, Ichien, & Qu, 2015; van Hoorn, McCormick, Rogers, Ivory, & Telzer, 2018). Because adolescents also typically have larger social networks than younger children, they may be influenced by a broader range of social contexts and identities. Finally, biology is a complicating factor, as pubertal hormones can shape emotional reactivity and other aspects of SR (Dahl et al., 2018). Biology can even alter the impact of social relationships; for example, it has been shown that the effectiveness of maternal support in stress regulation may be reduced for postpubertal youth (Hostinar, Johnson, & Gunnar, 2015).

### ***BCTs, SR and health promotion***

Adolescents can engage in BCTs that require self-reflection, abstraction, and metacognition such as comparing future outcomes and relapse prevention (Michie et al., 2013). Youth in weight management programmes who were encouraged to ‘bring the future to the present’ using episodic future thinking approaches wherein positive future events are envisioned as a result of behaviour change reduced their energy intake (Daniel, Said, Stanton, & Epstein, 2015), suggesting this may be a promising approach for individuals with a stated health goal. Yet, whereas adolescents may be competent in identifying health goals, a key element of many BCTs, they may reject adults’ preferred goals and health goals may conflict with more pressing priorities or social norms (Draper, Grobler, Micklesfield, & Norris, 2015). For example, a health goal to bring lunch from home may lose to an immediately rewarding social goal to eat fast food. Thus, although adolescence is a period of robust health in many ways, it is also a time of increased risky health behaviours and poor health-related decision making, even among youth managing chronic illness (Lansing & Berg, 2014; Wasserman, Hilliard, Schwartz, & Anderson, 2015).

Michie’s BCT taxonomy highlights the importance of rewards as well as the power of restructuring the environment in changing health behaviour (Michie et al., 2013). Adolescence is a period of social and environmental changes, heightened emotional intensity and reward focus, and goal fluctuation (Crone & Dahl, 2012). Thus, developmentally-informed BCTs to promote SR and health behaviours in adolescents will differ from BCTs used in younger children (Onrust, Otten, Lammers, & Smit, 2016). For example, one study employed a creative use of a BCT to provide information about social consequences to harness adolescent passions and promote positive health behaviour. Specifically, researchers tested whether a focus on healthy eating as a social justice rather than a health issue changed eating choices, and found that adolescents selected food and drink of higher nutritional quality when they focused on social justice compared with health (Bryan et al., 2016). Understanding how to engage both adolescents’ heightened reward sensitivity and engagement in the broader social world may be critical to developing BCTs that promote SR and health for this age group (Crone & Dahl, 2012; Dahl et al., 2018).

## **Future directions: a suggested roadmap for researchers**

### ***Identify developmentally-informed BCTs to promote SR and health outcomes***

As noted earlier, Hennessy et al.’s (2019) meta-review of BCTs to promote SR identified only two meta-analyses addressing children and youth, yet developmental differences became apparent.

Specifically, one meta-analysis found that parent modelling was more effective for younger children, whereas self-monitoring with mobile apps was more effective for adolescents' diet and exercise behaviours (Brannon & Cushing, 2014). Another meta-analysis found that BCTs using goal setting and monitoring (e.g., self-control and problem-solving skills training) worked best for substance use prevention among elementary and early adolescent-aged children, and to some degree for older adolescents, but that such approaches did not work for adolescents aged 14–16 years (Onrust et al., 2016). Further, most of the meta-analyses evaluated individual self-related BCTs (e.g., monitoring, goal-setting), with few addressing impulse control, stress reduction, or social-contextual factors (e.g., restructuring environment). Considering the nature of SR development as reviewed here, it makes sense that behavioural inhibitory control capacity may be more critical for shaping young children's actions compared with adolescents. Studies also suggest promoting intentional SR can be difficult in younger children given their more limited cognitive capacity (Steinbeis & Crone, 2016; Steinbeis, Haushofer, Fehr, & Singer, 2014). Future health-promotion interventions could therefore benefit from research that identifies which BCTs are effective for SR promotion at different ages. For example, testing whether BCTs that address inhibitory control in younger children have similar impact to BCTs that promote self-monitoring in older children in relation to the same health goal could be a direction for future developmentally-informed work. As shown in Table 1, different BCTs are likely best for promoting SR at different ages and in different social contexts; understanding these nuances is important in informing SR-focused health behaviour interventions in children and youth.

### ***Experimental medicine approach in behavioural interventions***

As limited intervention research in youth has focused on BCTs, we lack data on whether the SR processes that are hypothesised mechanisms of health behaviour change actually shift in response to BCTs. This is the goal of the experimental medicine approach, which entails identifying and testing mechanisms of change in identified targets, such as SR (Nielsen et al., 2018). Thus, identifying how BCTs can promote SR and in turn health outcomes among children and youth requires mechanistic, developmentally-informed research to identify which SR processes are responsive to which BCTs, and testing whether hypothesised changes in SR map to change in health behaviour. Such work could use designs such as factorial experiments (Collins, Dziak, Kugler, & Trail, 2014; Miller, Gearhardt, et al., 2018) and adaptive trials (Klasnja et al., 2015) that can carefully unpack which specific aspects of SR have potential for malleability, using which BCTs, in which settings, and at what age(s).

### ***Unpacking SR processes***

Future work could also examine how SR processes interact in order to develop BCTs that are responsive to different aspects of SR. For example, although impulse control may seem more critical for reducing reward-driven eating than for sticking to an exercise routine, it may also play a key role in the latter by reducing the impulse to engage in sedentary behaviour. Yet, the timing and interaction of such processes are not well-articulated. Further, although bottom-up processes such as impulse control are typically perceived as needed to be regulated, they can also play a critical role in regulating: for example, an immediate reaction to an alarming situation can orient our attention and invoke a top-down SR response, such as removing oneself from the situation. BCTs that act on multiple SR processes could also be effective in children, as aspects of SR develop independently early in development but become increasingly interconnected, such that one aspect of SR may enhance another (Montroy et al., 2016). For example, children who are able to manage their responses to stress and recover quickly may more readily engage in peer social interactions that allow them to practice and build advanced regulatory skills such as social perspective taking. In contrast, a child who struggles with stress regulation or impulse control may experience increasing

difficulties as environments become more complex and present greater SR challenges (e.g., transition to a new school).

### **Considering moderators**

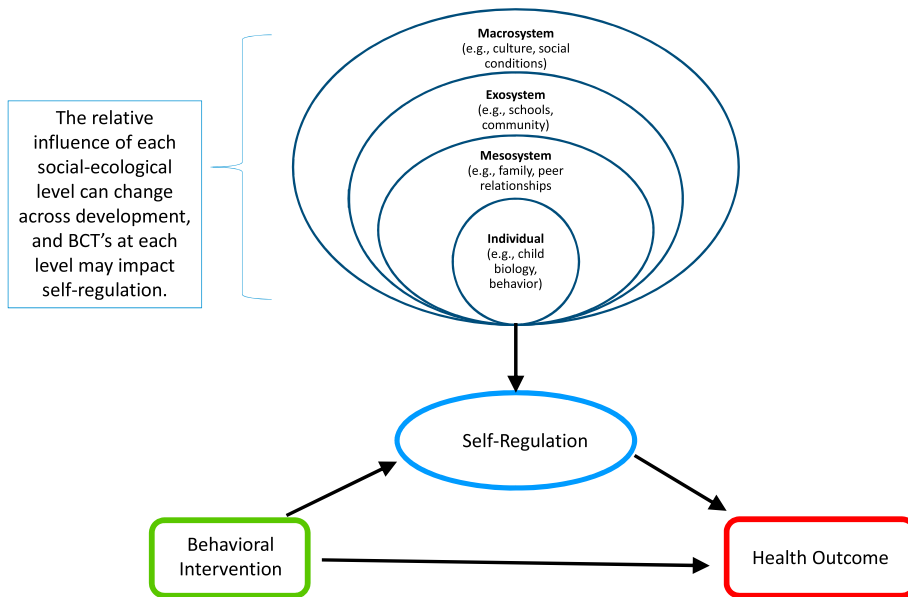
Future work must also examine factors that moderate the impact of BCTs on SR. Not everyone requires the same level of SR or BCT support and SR itself may moderate intervention impact (Hagger et al., 2019). Studies have found that SR-focused interventions are more effective for children who are lower in SR to begin with (Blair & Raver, 2014; Takacs & Kassai, 2019; Tominey & McClelland, 2011). Individual differences in reward sensitivity are also likely important, and reward sensitivity may also change with development, as noted above. Eating behaviour research in adults has found that gaps between intended and actual behaviours are wider among individuals with more disinhibited eating styles (Reichenberger, Smyth, Kuppens, & Blechert, 2019), and impulsive eating moderates intervention impact in some (Houben, 2011), though not all (Chen, Veling, Dijksterhuis, & Holland, 2018) studies. Reward sensitivity may peak in adolescence, but it has also been associated with eating behaviours (De Decker et al., 2016) and behaviour problems (Morales et al., 2019) in younger children. Thus, reward sensitivity is likely an important moderator to test across development. Of course, as broader social-contextual factors can also moderate intervention impacts, it is also important to test BCTs among child and youth populations living in underresourced environments, such as poverty (Blair & Raver, 2014).

### **Measuring SR ‘in the wild’**

Finally, to integrate SR into health behaviour interventions and best understand when and where BCTs are needed to promote SR, we must more precisely articulate the timescales on which different SR processes interrelate and how they relate to health behaviours. To do so, research must measure both SR and health behaviours in the field (Reichenberger et al., 2019). Developmentally, it is important to assess how BCTs may promote SR in contexts that require different SR demands, such as paying attention in the classroom versus making healthy choices in the lunchroom. As most SR research has been conducted in homogenous, Western populations, resulting in common assessments being culturally or cohort specific (Carlson et al., 2018; Lamm et al., 2018), future work must attend not only to developmental concerns (e.g., when do cognitive control strategies emerge? how can we measure them?), but also the meaning and measurement of SR from a broader socio-cultural perspective.

### **Conclusions: BCTs to enhance SR in children and youth**

Most SR interventions reviewed here seek to address individual-level change. Individual SR capacity becomes increasingly influential across development, as individuals choose environments that in turn shape behaviour (‘niche-picking’ (Sameroff, 2010)). Yet, individuals exist within social relationships and contexts that impact the likelihood of individual SR interventions to effect change. Developmentally-informed BCTs must operate at multiple levels (see Table 1 ‘social context’ column). Children are also nested within multiple social-ecologic contexts (see Figure 2), with limited autonomy in health-related routines and decision-making. Even health-specific goals related to chronic illness management may be chosen by parents or paediatricians and are not ‘owned’ by the child, creating an inherent motivational challenge (Lansing & Berg, 2014; Schwartz & Drotar, 2006). Such challenges become more complicated with development as competing goals arise, creating additional difficulties in designing developmentally sensitive BCTs. SR-focused interventions in children and youth therefore must consider not only the developmental stage of an individual child but also the affordances of developmentally salient social contexts in which an intervention is implemented (Bailey & Jones, 2019). For example, developmentally-informed BCTs could be used to enhance early



**Figure 2.** Social-ecological influences on self-regulation in children and youth.

Note. SR is influenced by factors across multiple social-ecologic levels. To be most effective, interventions and BCTs need to account for the nesting of an individual child within his or her environment, as well as developmental stage.

childhood SR via parenting routines or by restructuring preschool environments. Formative research to articulate BCTs that promote SR in relation to health behaviour change is needed in order to address complex questions regarding individual motivation for behaviour change in children and youth, and how to restructure social-ecological environments such that healthier choices are more appealing. Interventions to promote SR can be implemented at different social-ecologic levels (see Figure 2), from the macro- or exosystem (e.g., tax policies on carbonated soft drinks) to the mesosystem (e.g., family-based weight-loss programmes). Although individual SR strategies are often required to manage daily challenges, implementing developmentally sensitive BCTs through strategic contextual supports may ultimately reduce the need for SR in order to engage in healthy behaviours (Duckworth, Gendler, & Gross, 2016). In sum, specifying the developmental timing of SR-focused interventions and how factors at different contextual levels may facilitate or constrain SR processes are foundational next steps in using BCTs to foster SR across development and creating SR-informed intervention approaches to promote positive health behaviours for children and youth.

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