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1 Introduction

As demonstrated by the Dunedin Multidisciplinary Health and Developmental Study from New Zeland that followed up over 1000 participants from birth to adulthood, self-control in childhood is more important than socioeconomic status (SES) or IQ in predicting adults' physical health, wealth, life satisfaction, addiction, crime, and parenting of the next generation (Moffit/Arseneault et al. 2011; Poulton/Moffitt et al. 2015). Hence, it seems important to know how self-control is associated with self-regulation and how corresponding skills develop throughout early childhood (for a discussion of different factors potentially contributing to this development see Leve/DeGarmo et al. 2013).

To promote research along these lines, we first provide the reader with a brief overview over existing theoretical approaches to define the concept of self-regulation (1). Based on some conceptual clarifications, we introduce the EDOS (Early Development Of Self-regulation) model (2). Here, we assume that newborns rely on the help of caregivers who coregulate their physiological and mental states and behavior. Later, children gradually develop the ability to self-regulate. Any theoretical model explaining age-related changes in self-regulation during early childhood thus needs to account for the transition from co- to self-regulation. The EDOS model addresses this issue, describing the complex interplay of external and internal regulation in more detail. The third section of this report will take a closer look at implications of coregulation for measuring self-regulation skills in laboratory tasks (3). As will be demonstrated, any instructed task presented to a given child involves coregulation provided by the experimenter at different stages of the process, starting with the preparation of the material and ending with the feedback provided following each trial. To describe the how coregulation influences children's performance we propose the PROSECO model (PROcess of SElf- and CO-Regulation) and highlight its relevance for instructional settings.

2 Concepts and models

2.1 The concept of self-regulation

Self-regulation is typically used as an umbrella term for rather divergent aspects of adaptive behavior (e.g. Grouzet/Sokol et al. 2013; Matthews/Schwean et al. 2000). Hence, one can find many different definitions and models describing processes and mechanisms of self-regulatory control (e.g. Bridgett/Oddi et al. 2013; Diamond 2013;

1 The EDOS group includes the following researchers who all contributed to developing the EDOS- and the PROSECO model (listed in alphabetic order): Bechtel, Sabrina / Cierpka, Manfred / Gärtner, K. / Hertel, Silke / Holodynski, Manfred / Kärtner, J. / Rauch, Wolfgang A. / Reuner, Gitta / Sidor, A. / Voigt, Babett / Vonderlin, Eva / Wissner, Julia.

Hofmann/Schmeichel et al. 2012; Zhou/Main 2012), sometimes referred to as “executive functions”, “effortful control”, or “emotion regulation”.

Executive functions (EF) allow for conscious control over thoughts and behavior directed toward a goal (Carlson 2005; Miller/Marcovitch 2015; Zelazo/Müller et al. 2003). Following the predominant view (e.g. Diamond 2013; Garon/Bryson et al. 2008; Miyake/Friedmann et al. 2000), three separable albeit interconnected executive functions can be identified in adults: (a) *working memory* or *updating* allows us to keep different aspects in mind and mentally manipulate them at the same time, (b) *attention shifting* enables us to change the focus of our attention flexibly, and (c) *response inhibition* helps us to suppress dominant responses. Studies on executive functions in early childhood are still rare, because it is difficult to design tasks suitable for testing infants and toddlers on these skills (McGuigan/Núñez 2006). Hence, we still do not know whether the structure describing EF in school-aged children (e.g. Lehto/Juujärvi et al. 2003) and adults (e.g. Huizinga/Dolan et al. 2006) is also valid for younger children (Garon/Bryson et al. 2008). The few existing studies addressing this issue suggest a lack of cohesion and stability of EF measures during early toddlerhood (see Miller/Marcovitch 2015 for a recent overview) and leave open the question whether EF functions get differentiated or become integrated in early childhood. In general, executive functions are considered to undergo important qualitative and quantitative changes with age (Diamond 2002; Wiebe/Lukowski et al. 2010) which can be explained by a combination of brain maturation and environmental influences (Diamond/Lee 2011; Diamond 2012).

The components of inhibition and attention shifting also play a key role for *effortful control* (Liew 2012). Effortful control is typically interpreted as one important dimension of a given child's temperament, describing how well children are able to control their attention, to inhibit a dominant response, and/or to activate a subdominant response *(*Kochanska/Knaack 2003; Rothbart/Bates 2006). Some researchers interpret effortful control as one sub-component of executive functions (Diamond 2013; Fuster 2008) while others argue that both concepts are more likely to reflect variations in research approaches (studying inter-individual differences vs. intra-individual changes) than differences in developmental constructs (Zhou/Chen et al. 2012). In general, one can say that executive functions and effortful control show a high degree of conceptual overlap but each highlight different aspects of the general phenomenon of self-regulation.

In the literature, executive functions have primarily been discussed in the context of solving intellectual problems while *emotion regulation* has primarily been discussed in the context of dealing with social and motivational challenges (e.g. Fox/Calkins 2003; Liebermann/Giesbrecht et al. 2007). Since emotional/motivational processes are typically associated with activations in the ventro-medial prefrontal cortex, and cognitive processes are typically associated with activity in the dorsolateral prefrontal cortex, some authors suggest a distinction between "hot" and "cold" self-regulation (Zelazo/Müller 2002; Zelazo/Cunningham 2007; Zelazo/Carlson 2012). Following Zelazo and colleagues the temperature of a given self-regulation task always varies with the specific mixture of hot and cold processes induced (e.g. Zelazo/Carlson 2012). As these arguments reveal, our understanding of self-regulation has improved substantially during the past decade but still requires further specification.

In the present context we define self-regulation as a purposeful mental activity that serves to modify ongoing cognitive, emotional or motivational target processes in order to adapt to a given situation (see also Figure 1).

In this context, *target processes* induced by a specific task, and *self-regulatory mechanisms* required to deal with these processes should be distinguished. Both can diverge in temperature. For example: it may well be that a given situation elicits emotions in a child (i.e. hot target processes) which can best be regulated by re-evaluating the situation in cognitive terms (i.e. by applying cold self-regulatory strategies). Whereas the temperature of a given task depends on the target processes activated, the temperature of self-regulation depends on the nature of the control processes resulting. Hence, it seems important to specify (a) whether a given situation is meant to induce cognitive, motivational and/or emotional target processes, (b) to what extent it actually elicits which type of target process in a given individual, and (c) what kind of regulatory strategies the individual applies to deal with the target processes activated.

Furthermore, we would like to point out that all three target processes are conceptually distinct from each other and may come into play at different stages of dealing with a given situation, as illustrated by the following example: When faced with a tricky problem, we may first get involved in cognitive target processes. If we are unable to solve the problem at once, we may need to motivate ourselves to go on, thus regulating our motivational status. And if we finally get frustrated because we really seem unable to find a solution, emotions come into play and need to be dealt with. Emotions and motivations can both be called “hot” because they are both associated with activities in similar brain regions and typically co-occur, but at the same time, they still remain discriminable target processes.

With respect to mechanisms of self-regulation, we differentiate between *up-regulation* and *down-regulation* (Bonanno/Papa et al. 2004), thus highlighting the fact that our mental system needs to continuously evaluate the relevance of ongoing target processes, and to determine which processes should be modified. Up- and down-regulation of any internal process can be achieved in multiple ways, involving distraction, focusing on certain aspects, changing perspectives, self-instructions, or self-calming. The application of such strategies will eventually lead to a modification of target processes, resulting in more or less appropriate adaptive behavior. Hence, we would also discriminate between *mechanisms* and *strategies* of self-regulation.

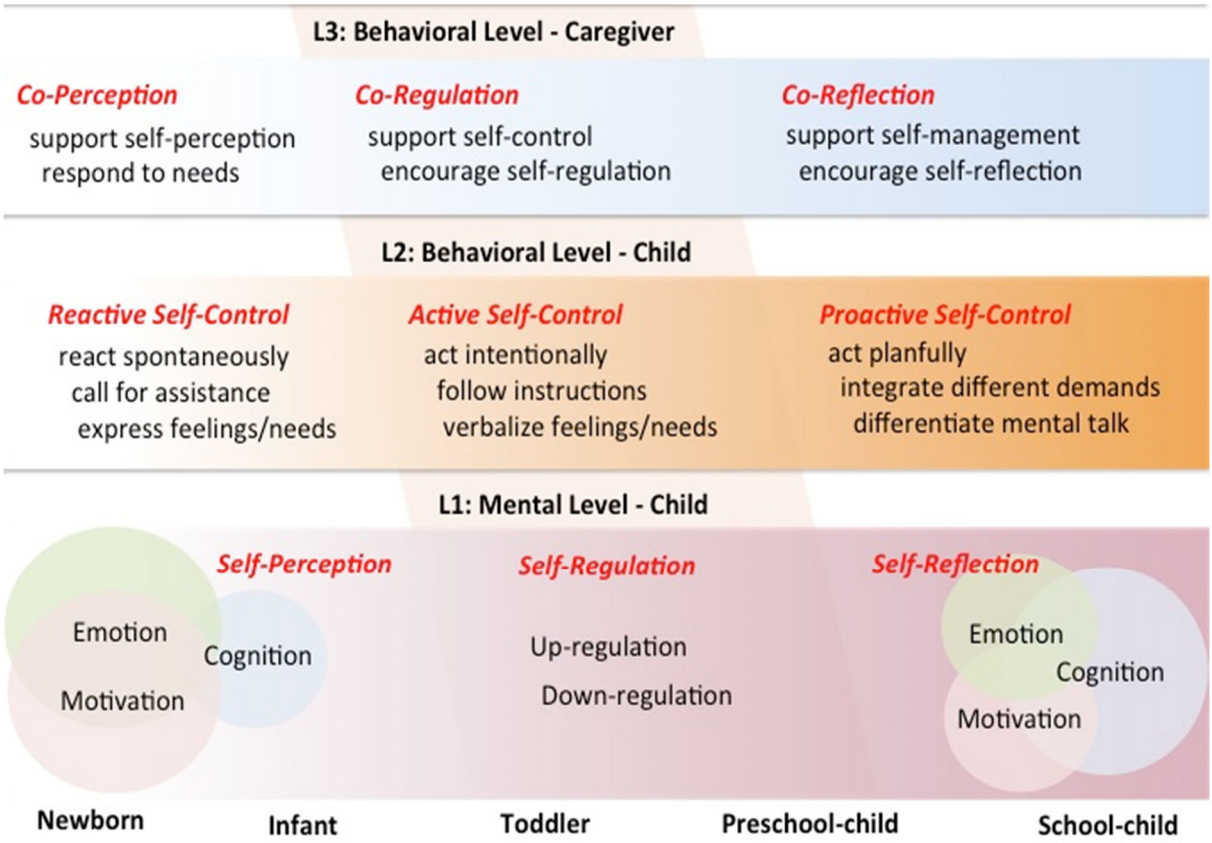
In sum we conclude that self-regulation is a complex human capacity. When talking about early childhood, we still know only little about how emotional, motivational, and cognitive processes interact, and how strategies of self-regulation develop.

2.2 The EDOS model

In line with existing work, we consider self-regulation skills to be multi-determined, but emphasize that the development of self-regulation strategies in early childhood can partly be explained by the internalization of coregulative strategies (Eisenberg/Spinrad et al. 2010; Holodynski/Seeger et al. 2013): Very young children are without any doubt highly dependent upon their caregivers when it comes to regulating their internal states. According to the predominant view, inter-personal regulation gradually leads to intra-personal regulation. Following Papoušek (2004) as well as Ho-

Iodynski and Friedlmeier (2006) who focus on co-regulation of emotional and motivational processes, infants first give unspecific signals, leading parents to act exploratively in order to meet the needs of the child. With age, signals of the child get more specific and the child acts more intentionally, thus enabling parents to deal with perceived needs and emotions more efficiently. In the next step, parents assist the child in learning how to regulate internal states in a more autonomous way (e.g. by providing reminders), until the child finally becomes able to show self-regulation even in the absence of any prompt from the caregiver. This gradual progress of "emancipation from the caregiver" is likely to be modulated by various internal and external factors (e.g. biological dispositions, child temperament, parental strategies, external stressors). In an attempt to (a) provide conceptual clarification, (b) describe general developmental trends across the early years, and (c) analyze when and how coregulative behavior of caregivers shapes the self-regulation skills of the child, our group proposes the EDOS model illustrated in Figure 1 and explained in more detail.

Figure 1: Early Development Of Self-regulation (EDOS)



Source: Own representation

Within the EDOS model we distinguish between three levels of analysis: ***Level 1*** refers to the internal (mental) level of the child, distinguishing different target processes to be regulated (motivational, emotional, cognitive processes), as well as different mechanisms of self-regulation (up-regulation, down-regulation). ***Level 2*** focuses on the behavioral level of the child, including active self-control, and ***Level 3*** addresses the interpersonal level, referring to behaviors of the interactive partner that aim at supporting

self-regulation in the child (i.e. co-regulation). Development from infancy to elementary school years is described as a process of gradual internalization leading to more reflective levels of self-directed activities. We assume that intervention strategies from caregivers (L3) are implemented in social interactions with the child at the behavioral level (L2), and that the internalization of corresponding experiences is crucial for the development of internal self-regulation and self-reflection (L1).

2.2.1 Level 1: Mental state of the child

The EDOS model distinguishes between target processes and self-regulatory mechanisms and strategies. ***Target processes*** refer to different aspects of the mind, namely to motivational, emotional, and / or cognitive processes induced by a given situation. Together these three components explain human mental activity from birth on. Basic needs and emotions dominate early infancy, and can hardly be discriminated from each other at this age, as illustrated by a large overlap of the corresponding fields (see Figure 1). This is due to the fact that any need elicits a corresponding emotion more or less automatically. Cognition becomes more prominent and influential with each year, increasing its overlap with emotional and motivational states while contributing to their differentiation at the same time. More complex and cognition-based emotions emerge during toddlerhood (e.g. guilt). With regard to motivational processes, basic needs are complemented by motivations, preferences, and personal interests, all showing a strong cognitive component (e.g. the motivation to please a specific person; the preference for a specific activity or topic). At this stage, emotional and motivational processes are still highly correlated but they can already get in conflict with each other (e.g. when a child is disappointed by a present but wants to please the giver). It seems important to note that motivational states gain importance for dealing with cognitive and emotional processes, because the child's behavior becomes increasingly intentional and self-determined with age. Consciousness gradually emerges as a result of brain maturation, cognitive growth, and social communicative experiences.

We assume that the experience of bodily results in states of ***self-perception*** which can already be perceived in very young children. According to Stern (1985) even infants show at least a rudimentary sense of the self. More specifically, the author speaks of an „emergent self" (0-2 months), or „sense of a core self" (2 to 7 months), respectively. Some time later, toddlers and preschoolers start to gain active control over their inner states, thus showing ***self-regulation*** for the first time. Specific target processes can now be up- or down-regulated in a purposeful way. For example: The up-regulation of a given cognitive aspect (e.g. voluntarily focusing on certain thoughts) may help to concentrate and/or to increase self-determination. Similarly, down-regulation leads to reducing the conscious experience of certain motivational states. The mechanisms applied to one process usually have an impact on others, thus leading to complex modifications in psychological states. To achieve up- and down-regulation, children develop specific *strategies* (e.g. self-soothing, self-instruction). With age, cognitive processes increase their impact on self-regulation of emotional and motivational states. When children grow older, they become capable of ***self-reflection***, thereby representing the self as invariant over time and space. Now they develop meta-cognition, elaborated mind-talk, and differentiated theory of mind understanding (Asting-

ton/Pelletier 2005). All these different skills contribute to improving self-awareness and self-regulation beyond early childhood (e.g. Focquaert/Braeckman et al. 2008).

The EDOS model suggests that self-regulation neither refers to processes of simply registering one's inner states, nor to reflecting on these states in an elaborated way. Children or adults involved in *self-regulation*, as defined here, purposefully modify certain mental aspects but they do not yet think through many different alternatives. The latter would imply self-reflection. Self-awareness and mechanisms of self-regulation first emerge during toddlerhood and show important further development during childhood and later years (e.g. King/Lengua et al. 2013). Self-reflections can be seen as an elaborated form of self-regulation with a strong cognitive component. Each step builds up on the previous one - without replacing it, but rather adding a new level of self-reference to the mental life of the child. This interpretation shows close resemblance with the hierarchical competing systems model (HCSM) of Marcovitch and Zelazo (2009) and the levels of consciousness model (Zelazo 2004) which describe the emergence and early development of executive functions.

Related to this issue, we should discriminate clearly between the meaning of self-regulation as a skill (disposition, temperamental characteristic), a mechanism, and a process. Conceptual clarifications in terminology will help us to improve our research by specifying what we are actually focusing on.

2.2.2 Executive functions and the EDOS model

How might different aspects of executive functions fit in the EDOS model? In our understanding, ***working memory*** links self-regulation to self-awareness. Only if the child can remember a previous mental state will she be able to become aware of any changes in this state. Furthermore, working memory may modulate the application of self-regulatory mechanisms based on cognitive processing: The better a given child can keep in mind different thoughts, feelings or motivations at the same time, the better will she be able to "decide" which one should be up- or down-regulated in order to adapt to a given situation (Giesbrecht/Müller et al. 2010).

Shifting results from a combination of up- and down-regulation. The previously predominant target process needs to be down-regulated, whereas a subdominant target process needs to be up-regulated. When the target process is cognitive, this may imply a change in attentional focus (or rule) relevant for solving the given task. In that case, shifting is linked to working memory because the child needs to keep in mind more than one rule in order to decide which one to use. When the target process is more emotional or motivational, however, shifting may require to reverse an ongoing target process (e.g. stop wanting something, stop feeling in a certain way) and/or to replace it by a qualitatively different one (e.g. become interested in something else, feeling calm). Because this is hard to achieve, the child may just try to stop expressing his wishes and feelings. Hence, shifting of motivational or emotional target processes often requires response inhibition.

In our understanding, ***response inhibition*** addresses situations in which the child needs to control the expression of a given inner state or intention, thus describing the transition from internal (mental) processes (L1) to child behavior (L2).

2.2.3 Level 2: Child behavior

While all aspects mentioned so far refer to inner mental states, most tasks designed for assessing these aspects use behavioral measures, thus confounding self-regulation with the active self-control of behavior. This is a general problem inherent to all methods measuring psychological states based on behavioral correlates. Within the EDOS model, both levels are separated to highlight that they can be dissociated – even in early childhood. A given behavior may result from different self-regulatory processes. For instance, the initial impulse to hit another person may not be expressed because the child (a) wants to avoid punishment and up-regulates a motivational target process, (b) remembers what his mother told him about hitting others, and up-regulates a cognitive target process, or (c) tries to relax and down-regulate his anger. Observable behavior does not automatically reveal which target process has been regulated in which way. At the same time, we know that the ultimate goal of self-regulation is adaptation. For that reason, behavioral measures provide a valid outcome measure for any self-regulatory process.

Level 2 also serves as the central stage for transmitting self-regulatory skills from interactive partners to the child. We assume that regulative and reflective strategies will first be implemented at the behavioral level in direct social contact between the child and a significant interactive partner before they can get internalized and serve to regulate inner states (e.g. Vygotsky/Luria 1994). Different aspects, including child characteristics (e.g. biological dispositions, temperament) and environmental conditions (e.g. family stress) may affect this process, but social interactions always play a central role – especially in early childhood.

2.2.4 Level 3: Inter-personal level: Behavior of interactive partners

Caregivers are without any doubt highly important for young children's development of the self (Cuevas/Deater-Deckard et al. 2014; Fay-Stammbach/Hawes et al. 2014; Grolnick/Gurland et al. 2002; Hughes/Roman et al. 2014; Karreman/Tujil et al. 2006). During infancy, caregivers are primarily responsible for meeting the child's basic needs and for helping the child to become aware of his/her own target processes. But with age adults also start to set limits or express expectations, thus challenging and supporting the child to develop self-control. To assist in this development, caregivers may use different strategies, varying with the child's given age. First, they may become engaged in ***co-perception*** by mimicking or verbalizing the internal states of the child, thus supporting self-perception. Soon they may also show ***co-regulation***, encouraging the child to control her behavior, or helping the child how to cope with certain internal states on her own. Finally, they may show ***co-reflection***, engaging the child in a discourse about motives, feelings or thoughts, thus enhancing self-management.

2.3 The PROSECO model

In the literature, behavior that aims at helping children to regulate their internal states are often called *coregulation* (e.g. Evans/Porter 2009; Fogel 1993) or *scaffolding* (e.g. Clark/Menna et al. 2013; Hammond/Müller et al. 2012), with both concepts being closely tied to caregiver sensitivity (Ainsworth/Bell et al. 1974). Within the EDOS framework, we use coregulation as a synonym for inter-personal regulation, assuming

that it can address hot aspects (emotional and motivational target processes) or cold aspects (cognitive processes). ***Hot coregulation*** covers aspects of emotional or motivational scaffolding (Park 2010). ***Cold coregulation*** shows many parallels to the concept of cognitive scaffolding. Both concepts often overlap: Cognitive scaffolding strategies can modulate the motivational / emotional state of a child (e.g. by increasing interest in a given problem), and emotional scaffolding may involve cognitive strategies (e.g. suggestions how to reevaluate a given situation).

Any model explaining the beginnings of human self-regulation needs to take into account the transition from inter-personal regulation (i.e. co-regulation) to self-regulation. Newborns have very limited skills to self-regulate target processes. They still lack the ability to express themselves verbally. By crying, laughing, fussing, or being attentive, infants guide adults to provide an environment that supports well-being (e.g. Holodynski/Friedlmeier 2006; Papoušek 2007; Sroufe 1996). In healthy caregiver-child relations, the caregiver is sensitive to infants' signals, prepared to fulfill the basic needs of the child (e.g. Papoušek/Papoušek 1987), but should also provide opportunities to acquire self-regulatory skills by setting limits, providing incentives, or encouraging self-control. We thus assume that corresponding strategies will work best when being adapted to the child's developmental status. Verbalization and explanations should gain importance with age, as do challenges requiring the child to deal with external expectations and demands.

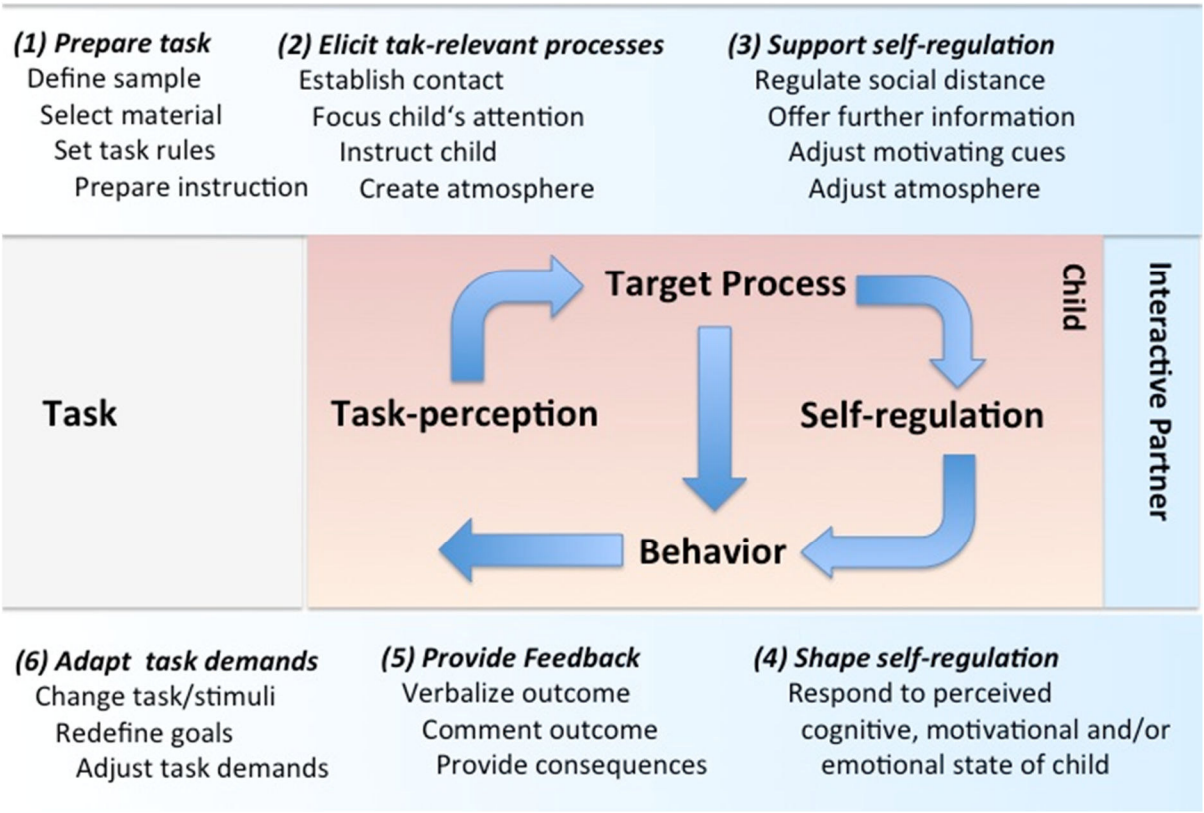
3 Co-regulation in instructional settings

Co-regulation and scaffolding strategies also play an important role with respect to cognitive processes (e.g. Bernier/Carlson et al. 2010; Neitzel/Stright 2003). Parents, teachers, and other adults teach the child to adapt cognitive processes by using means such as verbal instructions. To describe how interactive partners co-regulate the child in task-related contexts, we developed the so-called PROSECO model (PROcess of SElf and CO-regulation; see Figure 2). This model can also help to describe in more detail how experimenters interact with young children in laboratory settings:

Before the child even enters the lab or starts working on a given task, the experimenter/teacher *(1) prepares the setting.* She chooses a task, selects the material, sets the rules, and provides the instruction. Because the degree of self-regulation required by the child depends upon the goodness of fit between the child's needs and the task demands, this preparation phase reflects some kind of "prospective co-regulation". When the child actually visits the room, the experimenter/teacher (2) *elicits task-relevant target processes* by establishing contact, explaining or demonstrating what needs to be done, and focusing the child's attention on specific aspects as well as the procedure. Following this introduction phase, the experimenter/teacher may (3) *support self-regulation* in a more individualized way. She may offer additional task-relevant information, or adjust motivational and emotional cues to ensure that the child is well prepared to meet task demands (i.e. to self-regulate). Once the child has started to actually work on the task, the experimenter/teacher may perceive participants' responses and may want to (4) *shape self-regulation* by responding to the child's cognitive, motivational or emotional needs as displayed at the behavioral level while the child is still in the progress of dealing with the task. Often, this may include reminders of the instruction, reassuring the child emotionally, or motivating the child.

Supporting and shaping self-regulation are closely related. Whereas *supporting* is primarily relevant before the child actually starts to deal with the task, *shaping* only becomes relevant once when the child is already working on the task. As soon as the child shows a clear behavioral response to a given trial, the experimenter/teacher may (5) *provide feedback* by verbalizing the outcome, commenting on it, providing consequences (e.g. a reward), or reassuring the child (if necessary). Before the next trial/task begins, she may or may not (6) *adapt task demands*, by changing the stimuli, redefining the goals, and/or adjusting task difficulty. Figure 2 illustrates this process.

Figure 2: PROcess of SElf- and CO-Regulation in dyadic task settings (PROSECO)



Source: Own representation

Not all processes mentioned so far apply to any given task, and not always can we separate different sub-processes from each other in any strict sense (e.g. when it comes to tasks probing inhibition or shifting skills, the first step also includes the instruction to self-regulate). The purpose of our PROSECO model is to offer a general conceptual framework for specifying potentially relevant co-regulative interventions by interactive partners (e.g. experimenters, parents, teachers). Prospective self-regulation, as well as hot and cold co-regulation can be summarized under the heading *task-focused co-regulation* because they jointly serve to help the child in dealing with a given task.

Importantly, the PROSECO model suggests that the temperature of a given task is influenced by interactive partners who may either induce or modify ongoing cognitive, motivational, and/or emotional states in the child. The impact of such interventions on young children's performance in laboratory tasks (including tasks to assess self-regulation capacities) have long been neglected. Future work needs to put them in

focus. More specifically, we need to specify (a) during which phase of the experimental procedure co-regulation is provided in which way, (b) whether the experimenter offers a low, medium, or high degree of co-regulation, and (c) whether the co-regulation provided focuses on cognitive, motivational or emotional target processes.

4 Summary and concluding remarks

The main goal of this contribution was to show that developmental psychology can stimulate discussions leading to conceptual clarifications regarding self-regulation in many ways: First, we suggest a general distinction between mental activities and behavioral expressions related to self-regulation. A given person may show self-regulation at the mental level but no action at the behavioral level (e.g. when trying to remain calm in a moving situation). Alternatively, she may respond to external demands, thus showing adaptive behavior, while not being able to deal with the feelings accompanying this behavior (e.g. when following an order non-voluntarily to avoid punishment). We assume that the mental and the behavioral level become gradually separated during early childhood.

At the behavioral level, *reactive-, active-, and proactive self-control* should be discriminated to highlight the fact that behavioral responses may involve more or less conscious control. Spontaneous (reactive) responses of toddlers are not the same as well-planned behaviors that can only be observed in older children. Similarly we suggest to discriminate between *self-perception, self-regulation and self-reflection* at the mental level, assuming that these three capacities build up on each other, but require different degrees of consciousness. With regard to all capacities mentioned so far, the nature of the *target processes* (i.e. cognitive, motivational, emotional) should be distinguished from the *mechanisms* (i.e. up- and down-regulating) or *strategies* (e.g. self-instruction) underlying their modification.

Apart from the important question how we shall best speak about self-regulation and related terms, developmental psychologists are also highly interested in exploring how self-regulation skills are affected by external social interventions, often referred to as *co-regulation*. As we all know, a newborn infant is completely dependent upon her caregivers' ability to correctly identify her mental and physiological needs, thus helping the child to reach or maintain a physiological and emotional balance. With age, this vital need of coregulative interventions gradually decreases, while the ability to show self-regulation increases. This requires constant adjustments of coregulation by the caregiver. We claim that the adjustment of caregiver's interventions to this development, and the goodness of fit of the coregulative activities are highly predictive for the successful acquisition of self-regulation skills throughout development. This does not deny the impact of biological predispositions of the child for this process, but highlights the relevance of social experiences.

Furthermore, we need to keep in mind that coregulation as a critical factor influencing performance in experimental or learning task administered to children. More specifically, we claim that conditions of the task setting and the behaviors of the experimenter /teacher supporting self-regulation of the child in dyadic interactions are highly relevant for predicting child performance. Only if we keep in mind that corresponding outcomes are always a product of internal and external influences will we be

able to interpret findings regarding early development of self-regulation in a comprehensive way (Pauen 2002).

To describe the general development of self-regulation, we proposed the EDOS model, and to describe the process of co- and self-regulation in task-oriented settings, we proposed the PROSECO model. As stated at the beginning of this report, early self-regulation development seems to be highly predictive of success and wellbeing in later life. By conducting basic research on the nature and the development of self-regulation skills we may become able to design programs for promoting corresponding skills from early on, thus helping children to fully unfold their potentials.

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