

Conceptual and methodological approaches to the study of Self-Regulation: An inquiry within Developmental Science

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Review

Abstract

Resumen

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The present work intends to thoroughly identify theoretical and practical applications of self-regulation (SR) in contemporary developmental research, by reviewing conceptual and operational definitions of SR, in addition to the methods and instruments used to assess it in empirical studies. 468 scientific articles with cumulative evidence from the last two decades of research were included (142 reviews and 326 original research articles). Using a mixed-methods approach based on grounded theory methodology, the main theoretical and methodological aspects involved in the definition and operationalization of SR were reviewed. Results point towards a growing consensus in the conceptual definition of SR, which emphasizes the interrelation of emotional and cognitive control, goal-oriented activity, physiological and interpersonal processes. Empirical research often considers diverse biologic, behavioral and social features in the operationalization of the concept, making use of report scales, performance tasks and, to a lesser extent, physiological and observational measurements.

Abordajes conceptuales y metodológicos en el estudio de la autorregulación: una revisión en las ciencias del desarrollo

El presente trabajo se propone identificar y ahondar exhaustivamente en la aplicación contemporánea del concepto de la autorregulación (SR), incluyendo los métodos que se utilizan para evaluarlo en el campo de la psicología y la neurociencia cognitiva del desarrollo. Para ello, se revisaron 468 artículos científicos que acumulan evidencia de las últimas décadas de investigación en el área. Los resultados apuntan hacia un creciente consenso en las definiciones conceptuales, en torno a la interrelación multidimensional de procesos de regulación emocional, regulación cognitiva, actividad orientada a fines, esfuerzo conciente, procesos interpersonales y fisiológicos. Los abordajes operacionales presentan la consideración de diversos fenómenos de índole biológica, comportamental y social, haciendo uso de herramientas para evaluar la SR en distintos contextos del desarrollo y a lo largo del ciclo vital. Entre los instrumentos más frecuentemente utilizados se encuentran medidas de reporte, pruebas de desempeño y, en menor medida, medidas fisiológicas y observaciones estructuradas.

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Keywords: self-regulation, self-control, relational developmental systems, review.

Palabras clave: autorregulación, autocontrol, sistemas relacionales del desarrollo, revisión.

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Introduction

At the beginning of the present millennium, Posner & Rothbart (2000; 2007) identified the comprehensive study of self-regulation (SR) as a mayor objective for advancing an understanding of development and psychopathology. Nearly two

decades later, efforts made towards this goal by researchers stepping from multiple disciplinary backgrounds have condensed into a considerable body of published works, which grows more voluminous with each passing year.

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In a broad sense, SR stands for the ability to direct one's thoughts, attention, behavior and emotions in order to achieve goals (Vohs & Baumeister, 2016). The capacity to exercise control over motor, emotional and other cognitive processes develops as a result of complex interactions between an individual's genetic endowment and its life experiences (Bell & Deater-Deckard, 2007; Blair & Raver, 2012). Developmental science focuses in describing, explaining and optimizing intraindividual changes in adaptive developmental regulations, as well as the interindividual differences in such relations, across life (Lerner, 2012). Since developmental science is especially compelled to understand phenomena characterized by adaptive co-regulations among individuals and their environments, it follows that interest in process-relational constructs such as SR should be significant. The use of the term *process* (i.e., the ordered succession of acts), in the context of developmental science reflects the adoption of an epistemological stance, in which the fundamental categories employed for the analysis of developmental phenomena are *change* and *process*, as opposed to *stasis* and *substance* which derive from classic Cartesian reductionism (Overton, 2015). In this process-relational view, the historical and physiological events that constitute developmental change for either a single organism or a whole community are conceived as a set of complex transformational processes through which fundamental features of the dynamic systems relate, differentiate and move towards dialectic integration (Sameroff, 2010). Therefore, from this perspective, SR (in all of its conceptual variants) will be referred to as a process or as series of interdependent processes.

SR has been pointed out as an important aspect of people's behavioral adaptation to the demands of their social and physical environments, by means of different emotional skills, the ability to delay gratification and to comply with social norms, goal-directed cognitive control, linguistic and mathematical reasoning, among other competences that appear to be relevant for academic performance and optimization in multiple areas of functioning, across cultures (Eisenberg & Sulik, 2012; Lerner, 2018). Still, there remains much debate on how to define and measure SR. Some authors consider that scientific literature in this area lacks

theoretical order, and that disagreements in how to define self-regulatory constructs generates confusion that hinders the coherent integration of this body of knowledge (Cervone, Shadel, Smith, & Fiori, 2006). In this sense, it is important to mention that systematic review-based efforts have already been put into action by developmental psychopathologists in order to assess conceptual relations between different theoretical constructs (Nigg, 2017). In addition, an interesting meta-analysis on the convergent validity of heterogenous self-control measures was published almost ten years ago (Duckworth & Kern, 2011).

What exactly is SR it and how do we measure it? The need to tackle these issues constitute the rationale of the present work. Discerning the latest conceptual and methodological advancements in this matter would enable the reassessment of how developmental scientists study SR, and thus achieve a better understanding of how societies eventually could benefit from their insights.

Contemporary research paradigms in developmental science have been shaped extensively by philosophical debates on the concept of agency, systems theory and by technical breakthroughs in the field of neurobiology (Lerner, 2018). The identification of several mechanisms involved in neural plasticity, stress physiology and the development of attentional networks has sparked support for the integration of cognitive and temperamental psychobiological models (Rueda, Posner, & Rothbart, 2005; Williams et al., 2008). While perspectives on temperament and personality tend to emphasize the relative rank-order stability of self-regulatory traits over time and across contexts, cognitive frameworks usually underscore the idea that SR encompasses adaptive processes and that the executive function components can be trained and influenced by contextual factors (Bornstein et al., 2015). During infancy and early childhood, children gradually acquire the SR skills and strategies necessary to cope with a variety of developmental challenges, thus gaining autonomy, control and separate identities from their caregivers (Calkins & Fox, 2002; Posner & Rothbart, 2007).

Further on, researchers usually employ external behavioral measures as proxies to study internal regulatory processes. Coding systems for direct observation, controlled performance tasks,

self-reports, as well as caregiver and teacher questionnaires are the most common tools found in basic and applied research. However, each type of instrument has often been designed for specific purposes and may carry inherent strengths and limitations (Duckworth & Yeager, 2015; McCoy, 2019). For instance, scales designed for clinical or experimental settings are often considered limited in validity for studying how behavioral and emotional aspects of SR unfold in ecological contexts like school, work and other “real-world” social environments (McClelland, Ponitz, Messersmith, & Tominey 2010; McCoy, 2019). In addition, many questionnaires are vulnerable to reference and social desirability biases and thus are not recommended for program evaluation, inter-school accountability or individual diagnosis (Duckworth & Yeager, 2015). Although we do not intend to judge on the appropriateness of such methods, we consider it relevant to contextualize the goal of our work in the light of current debates that permeate this area of study.

Objectives

The purpose of this review was to delve into contemporary developmental research and discern the latest theoretical, technical and methodological advancements in the conceptualization and assessment of SR. In order to do so in an exhaustive and replicable manner, empiric research and review articles published in the current century were considered. We sought answers to the following questions:

1. How is SR conceptually defined?
2. Do operational definitions consider different levels of organization (i.e., molecular, cognitive, behavioral) and developmental settings (i.e., laboratory, home, school, community)?
3. Which indicators are used in psychometric assessments?.
4. Which instruments and designs are employed for data collection?

The potential benefits of accomplishing these objectives include (a) discerning consistent conceptual aspects to which other researchers can align their own definitions, hence reducing their level of ambiguity; (b) identifying knowledge gaps that call for more research; and (c) issuing clear methodological guidelines to assure that the conclusions to which new studies arrive have sufficient validity and result in useful insights for

the design of interventions and development policy.

Methods

Study design

Scientific articles on the typical development of SR in human populations, published either in English or Spanish by peer reviewed journals during the 2000-2018 period, constitute the main focus of this review. This decision is grounded in the exponential growth in the number of publications that has taken place in the fields of psychology and developmental cognitive neuroscience in the last two decades, which is related to technical and methodological advances in both disciplines and to the emerging theoretical perspectives for the integrated study of cognition and emotion.

The present review was designed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher, Liberati, Tetzlaff, Altman, & PRISMA Group, 2009; Shamseer et al., 2015).

Search strategy, data sources and extraction

Advanced search engine parameters were adjusted using keywords: self-regulation OR self-control; and incorporated filters: peer reviewed journals AND in humans. This choice of keywords is based in the interchangeable use that is often made out of these terms (Maranges & Baumeister, 2017; Vohs & Baumeister, 2016). Although a wide variety of terms associated to executive functioning, temperament and personality could have been chosen for this query, the lack of recursivity among these theoretical frameworks would have proven an obstacle for the straight forward identification of relevant literature, as authors do not always align these constructs as stemming from the same group of processes, nor make reference to over-arching concepts like SR or self-control. Data bases included in the EBSCOhost Psychology and Behavioral Sciences Collection and PubMed Biomed Central search engines were consulted, as these contain articles published in journals from the humanities, health and social sciences.

Data extraction and organization into spreadsheets was undertaken for each article that met all criteria to be selected for the review. This included ensuing variables: (a) journal name; (b) academic discipline and/or subdiscipline (defined

by authors' affiliations, journal type, methodology employed and indexing keywords); (c) year of publishing; (d) type of article (original research or review); (e) presence or absence of explicit definitions of SR; and (f) theoretical frameworks and authors cited in the paper's conceptualization of SR. For original research articles the following additional aspects were considered: (g) psychometric instruments used; (h) indicators observed by the assessment battery; (i) levels of organization considered during measurements (inferred from the indicators used); (j) temporal design of the study (cross-sectional or longitudinal); (k) nationality and (l) age range of their samples. Therefore, sections considered for data extraction were: title; journal and authors' information; abstract; introduction and literature review; methods; results; and discussion.

Data analysis

Data analysis consisted in the following mixed-method procedures: (1) Frequency analysis of previously enumerated variables using R, SPSS 15.0 and MS Excel 2016; and (2) Qualitative analysis of semantic categories employed in the conceptualization of SR utilizing Atlas.ti 7.5.18 software and following Grounded Theory guidelines (Justicia & Padilla, 2011; Strauss & Corbin, 1998). Atlas.ti aided in (a) data storing and organization by means of a manageable digital file (i.e., hermeneutic unit); (b) segmenting text fragments in which conceptual definitions or descriptions of SR were listed; (c) coding information; (d) establishing relations between assigned labels; and (e) generating graphical models for the representation of terms that were found in greater association with conceptual definitions of SR.

For this last step, the Word Count tool from Atlas.ti was used over collected text fragments. After filtering personal names, articles, pronouns, prepositions, interjections and redundant words, the most frequent key terms employed in the conceptual definition of SR were identified. A separate analysis was carried out to identify top quoted authors in these fragments. The outcome of the first word count was also used to generate categories that correspond to different aspects of self-regulatory processes. They were then applied to inquire further into the heterogeneity of conceptual definitions in the article sample, by relating one or more category to each

corresponding paper and then making comparisons between them based on other variables that distinguish sub-groups of articles (discipline, subdiscipline and age range of the samples).

The purpose of carrying on an open coding process, also known as microanalysis (Strauss & Corbin, 1998) was to complement the word count approach. Different codes were chosen to represent relevant conceptual features and theoretical frameworks that are usually encountered in self-regulation research, guided by the word count results and the authors' understanding of different research lines that permeate the field (Vohs & Baumeister, 2016). These codes were then used to label all the definitions in the sample, thus making it possible to pinpoint which theoretical features had a stronger presence in them. For more information on grounded theory and qualitative research methods, see Strauss & Corbin, 1998).

Results

Study selection and characteristics

Search results in February 2018 allowed the initial identification of 5296 articles, which were then screened for the following exclusion criteria: (a) duplicate results; (b) unavailable articles; (c) unrelated articles; (d) studies using sampling approaches that correspond to clinical, psychopathological, deficit or at risk populations (i.e.; socioeconomic risk, poverty, ADHD, cerebral paralysis, dyslexia, physical abuse, cognitive disfunction, autism, perinatal risk, mood disorders, premature birth, low weight at birth, language development delay, and drug abuse); (e) studies that do not focus on domain general aspects of SR, but on domain specific ones (i.e., self-regulated learning, SR of feeding behavior; SR in sexual relationships; SR of health behavior; neurofeedback, SR in sports, SR in meditation; SR in consumer behavior, SR in driving; racism and stigmatization, quality control, substance abuse, SR of wake; SR of work behavior, etc.); and (f) interventions. The final sample was composed by a selection of 142 reviews and 326 original research articles retrieved from 170 different journals. Figure 1 outlines these results by showing the flow of information throughout the different phases implemented in this review, based on the PRISMA guidelines (Moher et al., 2009).

When considering the claim that SR is

currently an expanding area of study, this review found in confirmation that the number of published articles since 2010 doubles the amount corresponding to the 2000-2009 period (Figure 2).

Populations studied in original research articles cover 40 different countries (Figure 3). Despite this great diversity, studies from North America hold a majority over the rest of the world

(57%) and transcultural studies are relatively few (7%).

In terms of researched age groups, it was found that the whole life course is contemplated in these empirical articles, but that studies involving only adult participants are the most numerous (50%) (Figure 4).

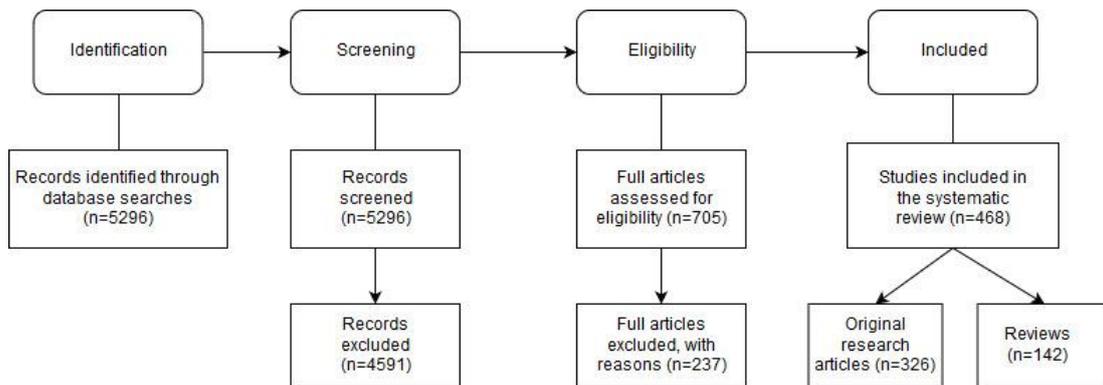


Figure 1. Flow diagram of the studies retrieved for the review.

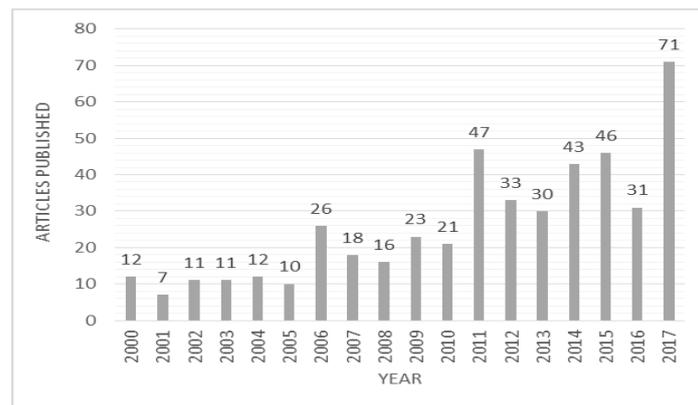


Figure 2. Number of articles published yearly

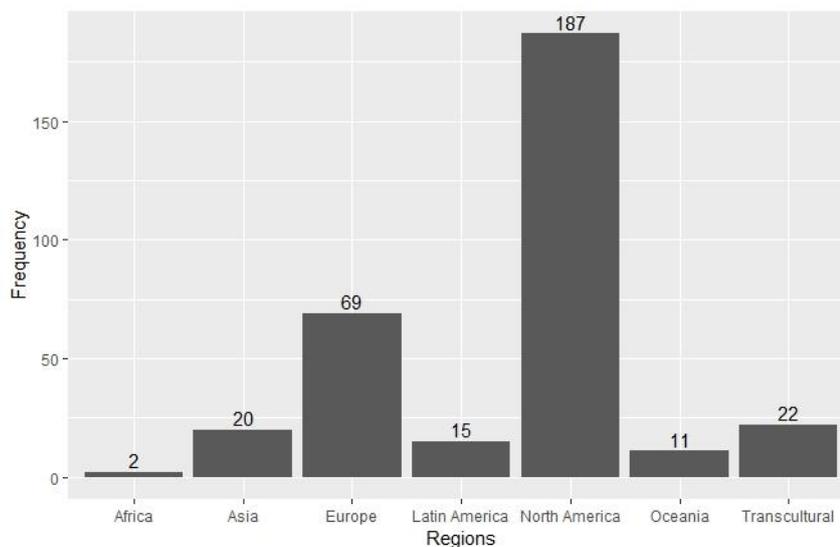


Figure 3. Distribution of empirical studies in the sample according to geographic region.

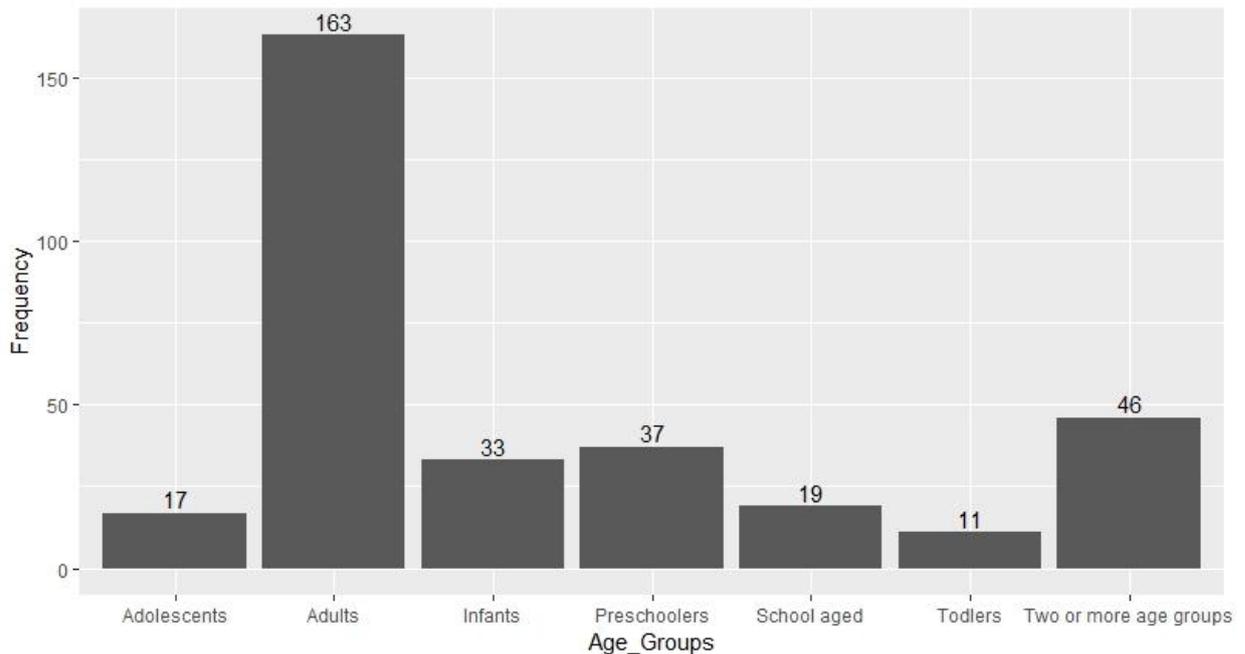


Figure 4. Distribution of empirical studies in the sample according to different age groups.

Research articles reviewed here belong to four different disciplinary backgrounds: psychology, cognitive neuroscience, health sciences and education sciences (Table 1). Psychology is the discipline from which more studies were originated (~81%).

Table 1. Percentage distribution of empirical studies in the sample according to different disciplines.

Discipline	Percentage	n
Psychology	80.98	264
Cognitive Neuroscience	11.67	38
Health Sciences	6.13	20
Education Sciences	1.22	4

Defining self-regulation from a developmental perspective

The present work's proposal is to generate a conceptual synthesis from the articles reviewed and to analyze the variability in the definitions offered by different article subgroups. Figure 5 shows the semantic composition of SR, in relation to the terms that are more frequently used to define it. Following this result, eight different categories were generated to qualitatively compare definitions across articles. Although they represent diverse features of self-regulatory processes, because they derive from different

lines of research, this does not imply that they are mutually exclusive or that they cannot conceptually overlap:

Cognition. It refers to the facet of SR related to cognitive control and those functions involved in information processing and instrumental reasoning, such as working memory, inhibitory control and attentional flexibility (Miyake & Friedman, 2012). Theories on Executive Functions are the main framework for this category.

Emotion. Emotional SR stands for the ability to initiate, inhibit, maintain, modulate and change the occurrence of internal emotional processes and their concomitant behaviors, like facial expressions and gestures (Eisenberg et al., 2000; Gross & Thompson, 2007).

Temperament. Such studies focus on constitutionally based individual differences in reactivity and SR, in the domains of affect, activity, and attention (Rothbart & Bates, 2006).

Goal-oriented activity. It refers to the motivational dimension of SR included in the management of behavior according to goals or objectives. This approach is distinctive of cybernetic models of SR, where feedback circuits play an essential role in the regulation of behavior (Carver & Scheier, 2000).

Interpersonal factors. It corresponds with the view that links self-regulated processes to psychosocial phenomena, as social interactions both shape the development of SR competences

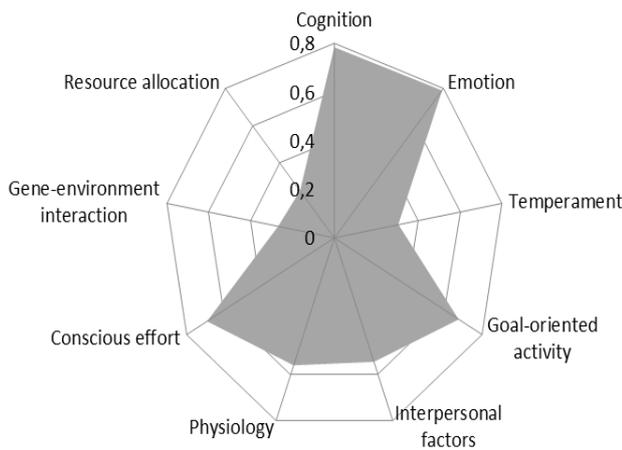


Figure 6. Conceptual profile of an average SR definition in the reviewed articles.

Note. This figure shows the percentual distribution of conceptual labels which were used to tag each of the 468 studies included in the review. Each paper could be tagged with up to nine different labels. For example, Emotion, the most frequently assigned label, was present in over 78.8% of the studies; and Resource allocation, the least frequently assigned label, only showed up in 25% of the articles reviewed.

When different groups of articles are observed separately, it is possible to appreciate that conceptual definitions of SR can vary according to an article's disciplinary background or to the age of the sample which was studied (in the case of empirical studies). Definitions from cognitive neuroscience and psychophysiological studies more frequently mention the incidence of physiological factors in SR phenomena. In turn, developmental psychology, health and education sciences studies more often name emotional and interpersonal factors. Temperament is a more commonly used category in infant and toddler studies, while mentions of goal-oriented activity and cognition increase relatively with the age range of the sample of articles included in the review.

As a final note to this section, the most influential authors in the conceptualization of SR were determined by the number of citations each author received in text fragments containing definitions. Top cited researchers include Mary Rothbart (380), Roy Baumeister (350), Michael

Posner (185), Nancy Eisenberg (161) and Grazyna Kochanska (141). All of them are psychologists based in the United States.

Instruments, indicators, temporal design, levels of organization and contexts of evaluation included in SR research

Instruments used to collect indicators at the behavioral level of organization, like report measures, performance tasks and structured observations, constitute around 92 percent of the total assessments registered. The remaining 8% is almost evenly distributed between measurements made at the physiological, neuroanatomical and molecular-genetic levels.

It was found that 14% of original research articles included in this review contemplate multiple contexts in their assessments (i.e., school, household, community centers). However, evaluations that take place only in laboratory settings represent the most frequent scenario in SR research (54%).

In addition, longitudinal research (i.e., studies where measurements are made at different time intervals) accounts for less than a third part of all the original research articles reviewed. In other words, cross-sectional design is still prevalent in this field of study based on the reviewed literature.

Also, the distribution of the type of instruments used for data collection was found to be the following: Self-report and other report measures together comprise 40% of total assessments, followed by performance tasks (25%), other laboratory tasks (21%), structured observations (6%), physiological measurements (6%), molecular-genetic analyses (1%) and neuroimaging techniques (1%). In Table 2, the names of the most frequently used measures in empiric research articles are shown.

Finally, a list with every variable used in the operationalization of SR in empirical studies was generated (Table 3). These indicators are mapped according to the type of assessment which they correspond to (i.e., cognitive, physiological, molecular-genetic, neuroanatomical, personality and temperament).

Table 2.

List of the top 30 instruments utilized in empirical studies.

Instrument	Type	Indicators	Frequency
1. Stroop task	Performance task	Working memory,	27

		Inhibitory control, Attentional flexibility	
2. Electrocardiograph (ECG)	Physiological measurement	Heart rate	23
3. Tangney, Baumeister, & Boone (2004) Trait Self-Control scale	Self-report	Trait self-control	22
4. Free-play situation	Structured observation	Externalizing behavior, Parent-child co-regulation	21
5. Child Behavior Questionnaire (CBQ; Putnam & Rothbart, 2006).	Other report	Effortful control, Negative Affectivity, Surgency, Extraversion	19
6. EEG recording	Physiological measurement	Event-related potentials	18
7. Gift Delay task (Kochanska, Murray, Jacques, Koenig, & Vandegest, 1996).	Laboratory task	Effortful control	14
8. Child Behavior Checklist (CBCL; Achenbach, 1991)	Other report	Internalizing/ Externalizing problems	14
9. Whole-brain blood oxygen level-dependent (BOLD) fMRI data acquired using an MRI scanner	Physiological measurement	Arterial oxygen saturation	13
10. Laboratory Temperament Assessment Battery (LABTAB; Goldsmith & Rothbart, 1993)	Laboratory task	Effortful control, Negative Affectivity, Surgency, Extraversion	13
11. Snack Delay task (Kochanska et al., 1996).	Laboratory task	Effortful control	12
12. Positive and Negative Affect Scale (PANAS; Watson, Clark, & Tellegen, 1988)	Self-report	Positive/Negative affectivity	10
13. Go/No-Go task	Performance task	Inhibitory control	10
14. Action control scale (ACS; Kuhl, 1994).	Self-report	Action control	9
15. DNA analysis by proteinase digestion and chloroform extraction procedure.	Molecular-genetic analysis	DNA sequence	8
16. Conners (1992) Continuous Performance Test.	Performance task	Inattentiveness, Impulsivity, Sustained attention, Vigilance	8
17. Infant Behavior Questionnaire (IBQ; Rothbart, 1981).	Other report	Effortful control, Negative Affectivity, Surgency, Extraversion	8

18. Brief Mood Introspection Scale (BMIS; Mayer & Gaschke, 1988)	Self-report	Positive/Negative affectivity	7
19. Family interaction tasks (Volling, McElwain, & Miller, 2002)	Structured observation	Externalizing behavior, Parent-child co-regulation	7
20. Crossing-out-letter task (Tice, Baumeister, Shmueli, & Muraven, 2007).	Performance task	Ego-depletion Sustained attention	7
21. Thought suppression task (white bear; Muraven, Tice, & Baumeister, 1998).	Performance task	Thought suppression, Ego-depletion	7
22. Early Childhood Behavior Questionnaire (ECBQ; Putnam, Gartstein, & Rothbart, 2006)	Other report	Effortful control, Negative Affectivity, Surgency, Extraversion	7
23. Behavioral Inhibition and Behavioral Activation Scale (Carver & White, 1994)	Self-report	Behavioral approach, Behavioral inhibition	6
24. Difficulties in Emotion Regulation Scale (DERS; Gratz & Roemer, 2004)	Self-report	Emotional regulation	6
25. Selection, Optimization, and Compensation (SOC) Questionnaire (Freund & Baltes, 2002)	Self-report	Goal pursuit	6
26. Self-Regulation Scale (SRS; Schwarzer, Diehl, & Schmitz, 1999)	Self-report	Attention control, Goal pursuit	6
27. Electromyograph (EMG)	Physiological measurement	Electrical activity produced by skeletal muscles	6
28. Clean-up sessions were coded for parent and child behaviors in 60-s intervals (Kochanska & Aksan, 1995)	Structured observation	Compliance, Parent-child co-regulation	6
29. Delay of Gratification task (Mischel, 1974)	Laboratory task	Delay of Gratification	6
30. Anagram puzzles (Baumeister, Bratslavsky, Muraven, & Tice, 1998).	Performance task	Ego-depletion, Sustained attention	6

Table 3.

List with indicators associated to the operational definition of SR in empirical research articles

Cognitive	Behavioral	Physio-logical	Emo-tional	Personality	Genetic mole- cular	Tempera- ment	Neuro- anatomical
abstract thinking	action control	arterial oxygen-saturation	anxiety	agreeableness	5-httlpr	activation control	cortical surface area
appraisal	adjustment	blood pressure	caring	character strenghts	BDNF	effortful control	cortical thickness
asimilation/ accomodat-ion	agression	correct-related-negativity	coping	Conscientious-ness	CHRNA4	fearfulness	grey volume matter
attention focusing	anticipatory looking	cortisol	depression	extraversion	COMT	regulatory-capacity/ orienting	subcortical volume

attention processing	antisocial behavior	critical frequency	fusion	emotion suppression	neuroticism	cumulative genetic-plasticity	soothability	white matter volumen
cognitive control	attachment	diastolic pressure	blood	emotional dysregulation	regulatory mode	drd4 genotype	surgency	
cognitive flexibility	behavioral approach	dynamic functional-network connectivity		emotional function-ing	shyness	maoa-u vntr genotype		
cognitive functioning	behavioral functioning	electromyogram		emotional intelligence	social fearfulness	SNAP25		
cognitive planning	behavioral inhibition	error-related negativity		emotional reactivity	state orientation/ action-orientation			
cognitive self-regulation	behavioral outcomes	error positivity		emotional resilience				
constructive thinking	behavioral self-regulation	feedback-related-negativity		emotional self-regulation				
crystallized intelligence	child externalizing behavior	frontal asymmetry		empathy				
delay discounting	competence	glucose uptake		frustration				
ego-depletion	compliance	glycaemia		interpersonal affect-regulation				
error correction	conformity to social-expectations	heart period		irritability				
error detection	delay gratification	heart rate		mood lability				
error monitoring	engagement	interbeat interval		mood state regulation				
executive attention	facial expression	late positive potential		negative/positive-affectivity				
executive control	eye gaze	n1 erp		proneness to anger				

executive functioning	goal pursuit	n100 erp	socio-emotional-competence
fluid intelligence	hyperactivity	n2 erp	socio-emotional-outcomes
future discounting	impulsivity	n200 erp	stress
Implementation - intentions	inattention	nc erp	stress reactivity
Inhibitory control	internalization of rules- of conduct	p1 erp	
intelligence	internalizing/ externalizing problems	p2 erp	
Intentional Self-regulation	joint attention	p3 erp	
interference suppression	lack of effort	p300 erp	
memory	mastery	p450 erp	
mental effort	mastery motivation	parasympathetic- flexibility	
metacognition	motivation	physiological-responsiveness	
mindfulness	motor control	respiration rate	
monitoring	obedience	respiratory sinus-arrhythmia	
negativity bias	oppositonality	resting state fmri	
orienting	parent-child co-regulation	skin conductance level	
perceptions of control	parent-child mutually-responsive orientation	slow waves	
planification	parental self-control	systolic blood pressure	
problem solving abilities	patience	testosterone	

promotion/ prevention- regulatory focus	peer cooperation	vagal activity
psychological flexibility	persistence/gr it/persev- erance	vagal recovery
reappraisal	positive youth- development	vertex positive potential
reasoning	private speech	
reflective awareness	problem behaviors	
response inhibition	prosocial behavior	
selective attention	risk behavior	
self-assurance	self-change	
self-awareness	self-control	
self-concept	self- determination	
self-efficacy	self-motivation	
self-esteem	self- regulatory- competences	
self-regulatory thought	self- regulatory- strategies	
self-worth	self-reliance	
shifting	self-soothing	
subjective self- control	self-talk	
sustained attention	social competence	
theory of mind	task attentiveness	
thought suppression	urgency	
thoughtful information- processing	visual attention	
updating		

visuospatial
working-
memory

willpower

working
memory

Note. ERP = Event Related Potential; 5-HTT = Serotonin Transporter; BDNF = Brain-Derived Neurotrophic Factor; CHRNA4 = Cholinergic Receptor Nicotinic Alpha 4 Subunit; COMT = Catechol-O-MethylTransferase; DRD4 = Dopamine Receptor D4; MAO-A = MonoAmine Oxidase A; SNAP2 = Synaptosomal-Associated Protein, 25kDa.

Discussion

Summary of main findings

Since the number of published articles on SR is rising, and since studies usually approach the subject from different theoretical and disciplinary frameworks, defining SR can often result problematic (Bridgett, Oddi, Laake, Murdock, & Bachmann, 2013). Some authors consider that scientific literature in this area lacks theoretical order, and that disagreements in how to define self-regulatory constructs generates confusion that hinders the coherent integration of this body of knowledge (Cervone et al., 2006). It has been noted that some works offer vague conceptualizations, with insufficient clarity or tautological statements (Burman, Green, & Shanker, 2015). In fact, the present study found that over a 30% of the articles reviewed did not define SR explicitly, but that readers are often left to make their own inferences or forced to interpret the meaning of the concept from the context in which it is used or from the presence of associated constructs. This finding is not incidental and has been reported previously (Barkley, 2001).

The results from the semantic analysis of text fragments that conceptualize SR can be summarized by stating that aspects which generally have a stronger presence in the conceptual definition of the construct are emotionality, cognition, goal-oriented activity, conscious effort, interpersonal and physiological factors. There seems to be a consensus that SR refers to the ability to activate, monitor and inhibit behavior, attention, emotion and other cognitive processes in a flexible and adaptive manner, in response to internal or external stimuli and for the achievement of desired purposes (Dias et al., 2014). It was found that the way in which researchers operationalize SR can vary according to their disciplinary background, theoretical framework, or even in relation to the

characteristics of the population they study. In other words, the description of self-regulatory processes that a researcher chooses can be biased by grounding disciplinary practices and also by the developmental stage which is being studied. Factors from the socio-cultural context can also shape research practices, acting like ideological frameworks (Kuhn, 1962; Latour & Woolgar, 1979; Lerner, 2018).

Growing interdisciplinary collaboration in the study of SR holds a hopeful prospect for unified definitions. Developmental scientists (i.e., psychologists, cognitive neuroscientists, health and educational practitioners) tend to utilize SR to designate processes involved in the development of conscious self-control over intentional activity, which includes cognitive, emotional, physiological and social phenomena that can be influenced across the life span by different biological and contextual factors.

Furthermore, original research articles contemplate SR phenomena at different levels of organization, including physiological, attentional, emotional, other cognitive and interpersonal functioning domains (Calkins & Fox, 2002). Many of these studies have paid attention to the everyday settings in which people develop and interact with each other, in their own houses or at educational institutions, for instance. However, this conception is not always followed by the use of appropriate instruments, methods and design to capture SR phenomena in a naturalistic or ecological manner. Despite this diversity in assessment contexts, the laboratory setting continues to be the most frequent scenario for SR research.

In the last decades, developmental theories have strived to leave behind simplistic approaches and conceptual reductionism, by taking into account the interactions that occur over time among different systems involved in human development (Lerner, 2006; 2018; Posner &

Rothbart, 2007). A shift into interdisciplinary perspectives is necessary to achieve real progress, with the incorporation of methods emerging from computing sciences, economic sciences, neuroscience, molecular biology, sociology, statistics and psychology.

Another of our objectives was to understand how researchers operationalize SR. This crucial phase in research design, in which variables or indicators are defined for their effective observation and measurement, allows phenomena to be approached empirically and quantitatively (Hernández Sampieri, Fernández Collado, & Baptista Lucio, 1991). The detailed inspection of methodological sections in empirical studies offers a general overview on how SR has been operationalized in recent years. While it is possible to appreciate the inclusion of genome sequencing techniques and physiological measures, like vagal autonomic nervous system activity, salivary cortisol concentrations and neuroimaging (i.e., FMRI, EEG, PET), their use is not widespread (Bell & Deater-Deckard, 2007; Sheese et al., 2007). The behavioral level of organization continues to be the focus of descriptions on cognitive and emotional control. Report scales, cognitive performance tasks and other laboratory-based procedures are among the main instruments implemented during empiric assessments of SR. Physiological and structured observational measurements in other than laboratory settings are scarce.

Both experimental and correlational methods are used in the study of SR (Eisenberg, Duckworth, Spinrad & Valiente, 2014). The present work focused in the temporal aspect of research design, because different reviews highlight the importance of chronologic sensitivity in the study of development and SR (Lerner, 2006; McClelland et al., 2010). Findings show that two-thirds of original research articles employed cross-sectional designs, but an increase in the number of longitudinal studies could be expected in the upcoming years. Many authors that make use of cross-sectional designs remark the need to adopt longitudinal approaches as an important future direction. In addition, while the study of how SR develop takes into account the whole life cycle, our results show that adult samples are overrepresented. The study of SR during infancy, childhood and adolescence constitutes a crucial target for future research.

Despite SR has been studied in different cultures, the great majority of articles analyzed here have worked with North American samples. This means that not every conclusion to which these studies arrive to are generalizable to other cultural contexts, because variability in sociocultural patterns, like socialization practices, condition the development of SR processes (Liu et al., 2017). Efforts to tackle the study of SR and its development in local cultures through original research proposals, scale adaptations and replication studies, continues to be an imperant necessity for public policy planning.

Concerning the debate on whether SR should be considered a number of fixed, context-independent traits or a group of skills that can be improved, the present scientific consensus holds that despite the construct appears to show relatively rank-order stable features over time in the absence of exogenous forces (i.e., intentional intervention, life events, changes in social roles), evidence is at odds with the connotation of immutability, because it has been demonstrated that such personal qualities are potentially responsive to intervention and dependent on situational factors for their expression (Duckworth & Yeager, 2015). As for the problem of increasing reliability and validity in the assessment of SR, perfectly unbiased, unfakeable, and error-free measures do not exist at the present time, so multimethod, application-dependent approaches to measurement are desirable in order to transcend the limitations and exploit the strenghts of individual tools (Duckworth & Kern, 2011; Duckworth & Yeager, 2015; McCoy, 2019).

Limitations

The purpose of this review was to identify contemporary conceptualizations of SR in normative developmental research, including theoretical definitions and methods used to assess it. This reduction constitutes the scope of our work and it necessarily leaves out contributions from clinical research, interventions programs and domain specific studies on SR, like self-regulated learning or SR of health behavior. Although such studies definitely provide different and valuable views on SR research, the amount of published works on these issues alone would justify that they are reviewed separately.

It is possible that the databases that were consulted did not index all existing articles on the

normal development of SR. In such case, relevant studies that could modify the results of our analysis may have been left out, unintentionally. Because of this, the conclusions to which this review has arrived must be contemplated within the limits of our sample. Furthermore, the restrained or simplified use of keywords in our search strategy can be considered another important limitation, because the number of articles associated to constructs like executive functions, temperament and personality (which are intertwined in the theorization of SR) greatly exceed those that are properly labeled or addressed as part of the SR literature.

Another limitation is that despite abidance to PRISMA criteria and the sole consideration of peer reviewed journals, in order to guarantee some methodological rigor, the authors cannot completely control the publication bias and therefore cannot guarantee full access to the data in the realm of this review.

Comparing the strength and suitability of different instruments for the assessment of SR requires a meta-analytical approach that is beyond the scope of this review and it is therefore an issue that should be addressed by future studies (readers interested in this discussion are advised to look into the following essays: [Duckworth & Kern, 2011](#); [Duckworth & Yeager, 2015](#); [McCoy, 2019](#)).

Conclusions

Developmental science has seen profuse conceptual, methodological and technical advancement in the study of SR over past decades. Current efforts in this interdisciplinary field seek to implement research designs that reflect a longitudinal, multidimensional and ecological view of self-regulatory processes, through diverse, age-appropriate, reliable and valid measures, that are sensitive to cultural variability and contextual influences ([Bell & Deater-Deckard, 2007](#); [Bridgett, Burt, Edwards, & Deater-Deckard, 2015](#); [McClelland et al., 2010](#)). The main aspect of SR that is usually emphasized in its definition is that multiple general domain processes are involved in the development of conscious self-control over intentional activity. SR processes include interlocking cognitive, emotional, physiological and social phenomena that can be influenced across the life span by different biological and contextual factors.

However, there is still not sufficient agreement on the specific pathways that coact in the development of SR, nor on the exact degree in which SR processes can be altered for the benefit of individuals and their communities. These will probably continue to be important issues during the next decades of research.

Author Contribution Statements

J.I.N, and S.J.L. were involved in the design of the study. Data were collected by J.I.N. with the assistance of S.J.L. Data analysis and writing were performed by J.I.N., M.S.S., and S.J.L.

Conflict of Interest Statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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