

Are Older Adults Less or More Physiologically Reactive? A Meta-Analysis of Age-Related Differences in Cardiovascular Reactivity to Laboratory Tasks

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In this meta-analytic review of 31 laboratory studies, we examined if relatively older adults showed lower or higher cardiovascular reactivity compared with relatively younger adults. Results revealed that age was associated with lower heart rate reactivity but higher systolic blood pressure (SBP) reactivity during emotionally evocative tasks. Consistent with the predictions of dynamic integration theory, the result for SBP was moderated by the degree of task activation. These data are discussed in light of existing self-regulatory models and important future research directions.

Key Words: Age—Emotion regulation—Health—Reactivity—Stress.

AGING is associated with changes in physiological function (Ferrari, Radaelli, & Centola, 2003; Timiras, 1994). Many of these age-related differences during rest or in response to exercise are well documented (Moore, Mangoni, Lyons, & Jackson, 2003). For instance, there are age-related differences in resting cardiovascular function, such as increased blood pressure (Lakatta, 1993). In addition, adrenergic receptor responsiveness is decreased as a function of age (Bertel, Buhler, Kiowski, & Lutold, 1980). However, sympathetic nervous system (SNS) activity is typically elevated in older individuals due to increased hormonal spillover from nerves and reduced clearance (i.e., elimination) of SNS neurotransmitters (Moore et al.). These findings illustrate the complex and potential compensatory changes (e.g., decreased receptor responsiveness due to increased hormone levels) that occur in an attempt to maintain the physiological capacity of the aging adult.

Much less is known, however, about the influence of age on biological reactivity during emotionally evocative tasks (Levenson, 2000; Uchino, Holt-Lunstad, Bloor, & Campo, 2005). Understanding the links between age and physiological reactivity is important because it can inform existing theoretical models about how older individuals self-regulate in response to emotional activation (Carstensen & Mikels, 2005; Coats & Blanchard-Fields, 2008; Labouvie-Vief, 2008; Magai, 2001). One perspective is represented by the literature on age and emotion regulation (based largely on self-report data), which suggests that relatively older individuals may be better able to regulate their emotions in response to stress and hence might be expected to show lower physiological responses during laboratory stress (Levenson). For instance, research examining mood states is consistent with the possibility that older individuals are at least equally skilled, if not better, at regulating their positive and negative emotions during daily life compared with relatively younger

adults (see review by Magai). Evidence from several large studies also suggests that older individuals show lower or no difference in negative affect (Stawski, Sliwinski, Almeida, & Smyth, 2008), with some studies showing greater positive affect in older individuals (Aldwin, 1991; Carstensen, Pasupathi, Mayr, & Nesselroade, 2000; Mroczek & Kolarz, 1998). Indeed, a number of laboratory studies from this age and emotion regulation literature have found that older adults show lower physiological reactivity to emotional stimuli (Levenson, Carstensen, & Gottman, 1994; Tsai, Levenson, & Carstensen, 2000). Hence, this “gain or same” perspective would predict that older adults should show decreased biological reactivity during exposure to emotional stimuli (Levenson), although much less work has been done within this perspective in the physiological domain.

A second model, however, is based on a “loss” perspective due to the known risk for disease as a function of age (Uchino et al., 2005). That is, due to basic physiological changes that occur with age, older adults may have difficulty biologically adapting to stressors more generally. This view would suggest that age is associated with increased reactivity to emotional tasks, which in turn may influence disease risk. This literature is based on the reactivity hypothesis that suggests elevated cardiovascular reactivity may influence the development and exacerbation of cardiovascular disease (Treiber et al., 2003). Consistent with the increased cardiovascular risk with age, studies within this paradigm have reported evidence for “greater” cardiovascular changes during acute stress as a function of age (Ginter, Hollandsworth, & Intrieri, 1986; Steptoe, Moses, & Edwards, 1990). Thus, this perspective would predict that age would be associated with increased physiological reactivity to emotional tasks, which may then influence disease risk.

A third more contextual perspective is represented by dynamic integration theory (Labouvie-Vief, 2008). According

to this model, changing cognitive resources in older adults may result in some positive changes in emotion regulation. However, conditions of highly arousing situations may result in the “breakdown” of systems that regulate cognitive-affective integration (Labouvie-Vief, 2008). In fact, the studies conducted under the rubric of the reactivity hypothesis might show evidence for greater reactivity with age due to the more evocative (stressful) tasks typically employed in such studies (Uchino et al., 2005). In one study from this program of research, researchers found delayed response latencies to more highly arousing words during a stroop task in older adults compared with younger adults (Wurm, Labouvie-Vief, Aycock, Rebucal, & Koch, 2004; also see Grünh, Scheibe, & Baltes, 2007). These data suggest that due to age-related cognitive changes, older adults may have difficulty processing highly arousing stimuli that would be predicted to increase physiological reactivity (Labouvie-Vief, 2008). Consistent with this view, poorer performance on cognitive assessments of verbal memory and executive function is linked to higher cardiovascular reactivity during acute stress (Waldstein & Katzel, 2005).

It is important to note that each of these perspectives would need to take into account the inherent complexity of the biological aging process (Lakatta, 1993). Potential self-regulatory differences are superimposed on basic age-related differences in biological activity and reactivity whose patterning may make general inferences challenging (Cacioppo et al., 1990). Kenney (1989) argued that “Aging may be defined as the sum of all changes that occur . . . with the passage of time and lead to functional impairment and death” (p. 15). Thus, a multitude of factors over time (e.g., health behaviors, socioeconomic status) provides the platform for interpreting age-related differences in biological reactivity to emotional events. As a result, it is important to interpret such changes in light of the existing theoretical models and basic work on age-related physiological changes.

The two most common measures utilized in age and physiological reactivity work include cardiovascular measures of heart rate and blood pressure. Heart rate reflects both neural- and receptor-level processes, especially the release, uptake, and elimination of SNS and parasympathetic nervous system neurotransmitters. In general, there is an age-related decrease in maximal heart rate (HR), which is evident in response to exercise and infusions of sympathetic agonists (Esler et al., 1995; Turner, Mier, Spina, Schechtman, & Ehsani, 1999). Thus, an age-related difference in heart rate may reflect a more basic difference in cardiovascular responsiveness that simply occurs over time and thus is evident across a number of different contexts (e.g., infusion, physical tasks). In fact, researchers have argued that age differences in heart rate reactions may be the least reversible of cardiovascular changes as it is still evident in highly trained athletes (Pugh & Wei, 2001).

Blood pressure, in comparison, is a more multiply determined end point in that it reflects differences in both

cardiac output and peripheral resistance. Cardiac output is a function of heart rate and stroke volume (amount of blood pumped per heartbeat), whereas peripheral resistance reflects both structural (compliance) and neural/receptor-level processes that influence more state-like changes in the vasculature (e.g., vasoconstriction). Analyses of vascular aging suggest structural changes that decrease vascular compliance and increase blood pressure (Ferrari et al., 2003). In fact, there is consistent evidence linking age to increased blood pressure reactivity during emotional tasks (e.g., Jennings et al., 1997). However, more general evidence for age-related differences in systolic blood pressure (SBP) reactivity during other tasks such as exercise is more equivocal (Fleg, Tzankoff, & Lakatta, 1985; Rodeheffer et al., 1984). Thus, age differences on blood pressure reactivity may be a better overall index of the self-regulatory capacity of the older adult due to its relative sensitivity to the context.

There have been several qualitative reviews of the link between age and aspects of physiological reactivity (e.g., Lau, Edelstein, & Larkin, 2001; Levenson, 2000). However, we are unaware of any quantitative synthesis of the literature that would allow for more general conclusions to be drawn on the links between age and physiological reactivity during laboratory tasks that involve stress or emotion regulation. As noted earlier, depending on the pattern of results (e.g., heart rate or blood pressure), such a meta-analysis may have implications for the different theoretical perspectives in the biological domain. As a result, we conducted a meta-analysis of existing studies that examined links between age and physiological reactivity during different laboratory tasks to inform these perspectives.

METHODS

Identification of Studies and Inclusion/Exclusion Criteria

A literature search was conducted using the ancestry approach and with PsycInfo and Medline by crossing the keywords age differences with cardiovascular reactivity, autonomic reactivity, or physiology. We only examined studies that reported direct statistical comparisons of age groups spanning at least 10 years. A difference in age groups of at least 10 years was deemed necessary for an adequate test that would not result in a restriction of range as most work on age and biological processes include at least this wide an age range (Lakatta, 1993). In addition, studies needed to examine reactivity (changes from pre to post) or account for baseline levels (or show that no baseline differences were present) in their posttask analyses. This is especially important because there are typically age-related differences in baseline physiological activity (Lakatta). Studies also needed an age range that included individuals older than 40 years in order to allow an examination of middle-aged/older adults as most of the age and emotion

regulation work involves these groups. Finally, there was only one longitudinal study to date on this topic and so it was excluded in the present analysis.

Based on these criteria, the meta-analysis included 31 studies (indicated by * in the reference list). Of these studies, all included information on links between age and heart rate reactivity during laboratory tasks. Age and SBP and diastolic blood pressure (DBP) reactivity studies were the next common with 20 studies each, followed by 8 studies that examined age and aspects of electrodermal (EDA) reactivity. Finally, six studies examined links between age and pulse transit time (PTT) measures. We did not conduct meta-analyses of any other autonomic assessment as they were utilized in only a small number of studies (i.e., fewer than five studies, finger pulse amplitude, impedance measures). However, when relevant we discuss patterns on these measures subsequently.

Analysis Plan

We first summarized the research examining age and autonomic reactivity during laboratory tasks by employing qualitative procedures. Major details regarding studies (e.g., age, type of laboratory task, main findings) were first characterized and examined in tabular form (see Supplementary Table 1 organized by type of task used in study). The subsequent meta-analysis was performed using a commercially available software package (Mullen, 1989) that provided detailed results regarding combined tests of significance levels, effect sizes, tests of variability regarding effect sizes, and a fail-safe number. The fail-safe n represents the number of studies that would be required to overturn the conclusions of the meta-analysis due to missing or unpublished (i.e., file drawer) studies (Rosenthal, 1984). When the test of variability associated with effect sizes was significant, we examined potential moderators based on characteristics of the studies from our qualitative analysis (e.g., gender composition, active vs. passive coping tasks). Results of the unweighted meta-analysis are reported, but analyses weighted by sample size were also performed and produced comparable results. To reduce the problem of nonindependence, when multiple assessments were reported (e.g., separate age analyses by different tasks), they were first transformed to a common metric (e.g., z scores), averaged, and then entered into the meta-analysis. Therefore, as recommended by Rosenthal, only one statistic was included from each study. Finally, when results were reported as nonsignificant, a conservative significance level of .50 was utilized (Mullen).

RESULTS

Overview of Studies

A qualitative summary of the studies in our meta-analysis is detailed in our Supplementary Table 1 and organized by

the type of coping task (i.e., passive, active, both; see subsequently). Two authors (W.B. and B.N.U.) verified the accuracy of the details listed in the table that was also subsequently used in the moderational analyses. Many of these studies included both men and women (58%). Across time, 2 studies were conducted in the 1970s, 11 were conducted in the 1980s, 8 in the 1990s, and 10 from 2000 to 2007. Most of the studies utilized a broad age range (80%), with the exception of six studies that primarily examined samples around 55 years of age. The only coding category that involved a qualitative decision was related to the active/passive coping task distinction. We directly coded for this task characteristic because many of these studies came from the stress reactivity literature, and this is a common psychophysiological distinction (Obrist, 1981; Sherwood, Dolan, & Light, 1990). Based on this literature, an active coping task is defined as a task in which an instrumental coping response was available (e.g., formulating a speech, completing math problems). In comparison, a passive coping task is defined as a task in which an instrumental coping response was not available (e.g., cold pressor task, viewing films). In independent coding of this task characteristic, there was only one case of disagreement that was resolved via discussion. Based on these codes, 24 (77%) studies utilized an active coping task, whereas 6 (19%) utilized a passive coping task (1 study utilized both).

Are There Age Differences in Autonomic Reactivity to Emotion-Based Laboratory Tasks?

The most commonly examined measures included in the review were heart rate and blood pressure reactivity. In general, the results of the meta-analysis for heart rate were consistent with the notion that age is associated with attenuated reactivity during laboratory tasks ($z = -7.63, p < .0001$, fail-safe $n = 636.4$). The average effect size was $r = -.16$, suggesting a small but reliable negative association between age and heart rate reactivity. However, the diffuse comparison of effect size was also significant, $\chi^2(30) = 80.9, p < .001$. The latter result suggests the presence of moderators of the association between age and heart rate reactivity that will be examined subsequently.

In comparison, results for blood pressure reactivity suggest that age was associated with greater reactivity during emotional tasks. Age was associated with higher SBP reactivity ($z = 6.72, p < .0001$, fail-safe $n = 313.6, r = .14$). Although age was associated with increased SBP reactivity, like heart rate, there was significant variability in effect sizes, $\chi^2(19) = 61.7, p < .001$. Age was also associated with increased DBP reactivity ($z = 2.62, p < .05$, fail-safe $n = 30.7, r = .03$). However, the fail-safe n is indicative of a potential file drawer problem as Rosenthal (1984) suggests $5k + 10$ (k = number of studies in review) as a guideline for ruling out such effects.

Analyses for EDA activity and PTT contained considerably fewer studies. Nevertheless, age was associated with lower EDA reactivity ($z = -2.11, p < .05$, fail-safe $n = 5.2, r = -.09$). Again, note that the small fail-safe n suggests the possibility of a file drawer problem. Finally, age was not associated with differences in PTT ($p = .19$).

What Are the Moderators of Age and Cardiovascular Reactivity?

Overall, two measures indicated increased reactivity with age, two indicated lower reactivity, and one indicated no effect. Of these findings, only two effects were not subject to file drawer problems (heart rate and SBP), and these findings were characterized by significant variability in effect sizes. As a result, we conducted several analyses to examine potential moderators of these reliable associations. We first examined basic demographic factors. However, the correlation between effect sizes (Fisher's z) and percentage of women in the studies did not reveal significant differences for heart rate (Fisher's $z = 0.18, p = .08$) or SBP (Fisher's $z = 0.12, p = .26$) reactivity. We were also interested if the health status of the sample moderated these results. In the biomedical literature, there is an emphasis on separating out age differences in physiological function that are not simply a result of underlying disease (Lakatta, 1993). Of these studies, four did not report whether the sample had been screened for health problems or if health problems were statistically controlled in the analyses (e.g., medication use). However, contacting the authors for three of the four studies resulted in information indicating that preliminary analyses not reported in the articles had taken the health status of participants into account (Labouvie-Vief et al., 2003; Levenson et al., 1994; Tsai et al., 2000). Thus, there was little variability in this factor as a potential moderator.

More important, we also examined task characteristics associated with each study. One suggestion in the literature is that older adults are more likely to rely on passive coping strategies (Folkman, Lazarus, Pimley, & Novacek, 1987). Hence, a match between the preferred coping strategy of older adults and the assumed task coping characteristics might produce a stronger test of the theoretical predictions. We thus examined whether active versus passive coping tasks explained part of the heterogeneity in effect sizes. The focused comparison for this blocking factor, however, was not significant in analyses of heart rate ($p = .07$) or SBP ($p = .13$) reactivity.

Another potential moderator is predicted by dynamic integration theory in which age differences in reactivity should be more pronounced under higher levels of activation, which can tax the coping resources of the aging adult (Labouvie-Vief, 2008). As a result, we calculated the average task heart rate and SBP reactions for each study (i.e., averaged across age groups) and examined if the degree of activation elicited by the tasks moderated these effects. We were unable to

calculate average heart rate reactivity levels in two studies (Garwood, Engel, & Capriotti, 1982; Powell, Milligan, & Furchtgott, 1980) and average SBP reactivity in one study (Garwood et al.) because mean levels were not reported. Nevertheless, results of these analyses revealed virtually no correlation between the effect sizes and average task reactivity for heart rate (Fisher's $Z = -.10, p = .15$). However, there was a significant positive association between the age-SBP reactivity effect sizes and average SBP changes (Fisher's $Z = .59, p < .01$). These findings provide partial support for the moderational hypotheses of dynamic integration theory in that a stronger association between age and greater SBP reactivity was related to more evocative tasks as indexed by average SBP changes during the stressors.

DISCUSSION

The main aim of this review was to examine the association between age and physiological reactivity during emotionally evocative laboratory tasks and its theoretical implications. Analyses of heart rate revealed evidence of better self-regulation during emotion-based tasks. However, analyses of SBP reactivity showed evidence for poorer self-regulation, an effect that was moderated by the degree of task activation as predicted by dynamic integration theory (Labouvie-Vief, 2008). We have argued that heart rate may reflect a more basic age-related difference, whereas SBP reactivity may be a better overall index of the biological response of the older adult during emotional tasks. Thus, these data appear to provide greater support for the reactivity and disease or dynamic integration perspectives. Although evidence was found for increased DBP reactivity and decreased EDA reactivity, these findings were subject to potential file drawer problems due to their small fail-safe n . As a result, more work will be needed utilizing these measures in future research so that stronger conclusions can be drawn. We now discuss the theoretical implications of these findings in light of the larger aging and biomedical literatures, as well as important directions for future work.

Linking Theory to Cardiovascular Reactivity

It is important to emphasize that the results from this meta-analysis reflect, in part, the complexity of the aging biological response. Potential self-regulatory differences and their theoretical implications are superimposed on basic age-related differences in biological activity and reactivity (Lakatta, 1993; Uchino et al., 2005). As a result, it is important to interpret such changes in light of the existing theoretical models and basic work on age-related physiological changes. We first found that older adults showed lower heart rate reactivity to laboratory tasks compared with relatively younger adults. The decreased age-related heart rate reactions are a combination of neural-receptor interactions that are due to declines and compensatory processes in the aging myocardium (Lakatta). More specifically, it appears to

reflect an age-related decrease in the concentration/sensitivity of myocardial β -adrenergic receptors, possibly linked to an age-related increase in cardiac SNS activity (Bertel et al., 1980; Seals & Esler, 2000). The overall net result is an age-related decrease in maximal HR. As argued earlier, this age-related difference appears to reflect a more basic change in cardiovascular reactivity. For instance, age-related differences in heart rate reactivity are seen across a number of challenges (i.e., exercise) and even in highly trained athletes (Esler et al., 1995; Pugh & Wei, 2001; Turner et al., 1999). Thus, the use of heart rate as an index to make inferences about how older adults respond to challenges in a specific context is difficult without relevant comparison conditions (e.g., activating tasks with less of an emotional component) and complementary assessments (e.g., appraisals). The use of complementary assessments would also provide stronger grounds for inferring that lower heart rate reactivity reflects "better" self-regulatory capacity.

In comparison, consistent with the increased disease risk with age, SBP reactions were greater in older adults compared with relatively younger adults. This is important because there is increased emphasis on the prognostic importance of SBP more generally in understanding cardiovascular disease risk (Lloyd-Jones, Evans, Larson, O'Donnell, & Levy, 1999). This age-related increase in blood pressure reactivity also appears to reflect underlying differences in neural-receptor processes but also structural differences in the aging cardiovascular system. Analyses of vascular aging suggest structural changes that decrease vascular compliance and increase blood pressure (Ferrari et al., 2003). There is also an age-related decrease in nitric oxide (an important contributor to vasodilation), as well as decreased responsiveness of blood vessels to adrenergic agonists (Elliott, Sumner, McLean, & Reid, 1982; Lyons, Roy, Patel, Benjamin, & Swift, 1997). Despite these changes, more general evidence for age-related differences in SBP reactivity during other tasks such as exercise is more equivocal (Fleg et al., 1985; Rodeheffer et al., 1984). These differences may reflect, in part, the relatively greater vasodilation that occurs with exercise (Smith & Kampine, 1990) in contrast to psychological stress. Overall, these data suggest that blood pressure changes may be a better overall index of age influences during stressful tasks due to its apparent sensitivity to the context (e.g., psychosocial stress, exercise). We offer this interpretation as a hypothesis, but future work that directly compares these indices using tasks that differ in their degree of psychological activation would be needed to provide stronger grounds for inference.

Analyses of potential moderators also revealed evidence for the prediction of dynamic integration theory (Labouvie-Vief, 2008). According to this perspective, due to diminishing resources, older adults are more likely to show decrements in self-regulation during high levels of arousal or activation. Consistent with this view, we found that the average level of task activation moderated the age-SBP reactivity link. That

is, larger effect sizes were associated with emotional tasks that resulted in a higher level of SBP changes.

Although these data are consistent at a very broad level of abstraction with the predictions of dynamic integration theory, it is important to note that additional data would be needed to warrant such an inference. Decreases in cognitive-emotional complexity during high levels of activation are predicted to be responsible for heightened stress reactivity (Labouvie-Vief, 2008). In fact, decreases in cognitive-emotional complexity appear to partially mediate the coping behavior of older adults (Coats & Blanchard-Fields, 2008). Future work that incorporates measures of cognitive-emotional complexity and assesses instrumental and passive coping responses in laboratory tasks as well is needed to directly model the predictions of dynamic integration theory. Such research could provide converging evidence at multiple levels of analysis (e.g., appraisals, positive affect, behavioral indices). In addition, research that manipulates the degree of task activation may provide a stronger test of this perspective.

Future Research Directions

There are several important future areas of research made salient by the present review. A first set of issues is related to more in-depth questions regarding the more specific biological processes responsible for broad-based blood pressure responses. It is important to note that blood pressure is a function of both vascular resistance (i.e., total peripheral resistance [TPR]) and flow (i.e., cardiac output). Heart rate contributes to SBP via its influence on cardiac output, and studies that have rigorously screened for healthy participants suggest that there is little or no age-related difference in cardiac output at rest or in response to exercise (Pugh & Wei, 2001). However, the mechanisms responsible for cardiac output reactions differ as a function of age. Older adults are less able to increase cardiac output through heart rate accelerations (due to the aforementioned age-related decrease in maximal heart rate) but achieve such changes through a compensatory reliance on increased end-diastolic volume via the autoregulatory Frank-Starling mechanism (i.e., end-diastolic volume increasing contractile force; Rodeheffer et al., 1984).

Given the larger biomedical literature that suggests little change in cardiac output, one might predict that the age-related difference in SBP to emotional tasks is driven primarily by age differences in TPR. There were only a few impedance cardiography studies on this topic that might lend insight into the determinants of blood pressure responses. However, studies that have found an age-related difference in SBP reactivity and utilized impedance-based measures found that there were age-related differences in both cardiac output and TPR during stress (Jennings et al., 1997; Uchino, Uno, Holt-Lunstad, & Flinders, 1999). Moreover, statistical meditational analyses suggested that both

cardiac output and TPR were responsible for age-related differences in SBP reactivity (Uchino et al., 1999). It is possible that these differences, compared with the exercise literature, reflect limitations in screening for the presence of disease (Uchino et al., 1999, used self-reported disease and medication use). However, Jennings and colleagues (1997) used a much more intensive medical screening in an attempt to separate disease from aging influences and reported the same pattern of results. So both cardiac output and TPR may contribute to age differences in blood pressure changes during these laboratory tasks.

A second set of future research issues has to do with expanding the contexts and measures that are used to test the biological implications of these theoretical perspectives. That is, research is also needed that extends the exploration of cardiovascular reactivity beyond laboratory-based studies. Carstensen, Isaacowitz, and Charles (1999) have argued that better emotional regulation is typically seen when older adults can select the contexts that maximize emotional regulation. However, due to the constraints in coping options during laboratory stress, these age differences may be reduced due to the removal of selection as a primary regulation strategy (Carstensen et al., 1999). However, we have found in a daily diary study that older individuals when exposed to daily stress also evidence higher blood pressure reactivity (Uchino, Berg, Smith, Pearce, & Skinner, 2006). Moreover, many of the prior self-report studies on age and emotion regulation examine how older adults deal with interpersonal stressors that are quite different from the types of tasks typically examined in laboratory studies (Birditt & Fingerhant, 2005). As a result, laboratory-field generalizations need to be made carefully.

The importance of acknowledging the limitations of the laboratory context is apparent because studies suggest that older adults experience fewer stressors in real-world circumstances (Stawski et al., 2008). In addition, older individuals typically report greater use of what has traditionally been called passive coping techniques, such as distancing, positive reappraisal, and argument avoidance, which may reflect differences in coping goals (Folkman et al., 1987; Sorkin & Rook, 2006). Of course, it is being increasingly recognized that such "passive coping" reflects a proactive and goal-effective strategy (e.g., preserving relationships) on the part of older adults to avoid or minimize the deleterious influences of conflict or stress (Blanchard-Fields, 2007). We found little evidence that the type of task as defined in many of these psychophysiological studies moderated these results in terms of its active or passive task characteristics. It is important to note that most of the studies in this review utilized what the physiological literature refers to as active coping tasks and only a few utilized passive coping tasks that were limited to either the cold pressor task or viewing films. Hence, future research using a wider range of active and passive coping tasks as well as the measurement of adults' appraisals of these tasks (e.g., Berg, Strough, Calderone,

Sansone, & Weir, 1998) will provide a stronger test of this possibility. It may also be particularly important to examine interpersonal coping paradigms using existing relationships, given age-related differences in relational coping (Berg & Upchurch, 2007; Sorkin & Rook).

As noted earlier, most of the studies utilized active coping tasks in which an instrumental coping response was available. The cardiovascular pattern most associated with active coping is an increase in heart rate and SBP (Obrist, 1981). Thus, many of these laboratory tasks may be better suited to test for potential differences on these measures. Moreover, due to the primary use of active coping tasks, there are at least two explanations for changes in cardiovascular reactivity during these laboratory-based tasks: affect and/or effort. Of these laboratory-based studies, only 20 studies examined task performance, self-reported task effort, and/or self-reported task affect (e.g., stress). Most of these studies reported no age-related differences on these measures (e.g., Barnes, Raskind, Gumbrecht, & Halter, 1982; Ginter et al., 1986; Uchino et al., 1999) or demonstrated that the age differences in cardiovascular reactivity were statistically independent of any differences (e.g., Carroll et al., 2000; Jennings et al., 1997). These results are consistent with the uncoupling that can occur between self-report and physiological assessments in laboratory paradigms. Thus, it is possible that age differences in self-reported affect or effort may reflect a different facet of the aging process. For instance, these measures may also be influenced by age differences in the use of accommodative coping strategies such as changes in goals and self-standards (Brandtstadter & Rothermund, 2002) and the integration of problem- and emotion-focused ways of coping in everyday emotional stressors (Blanchard-Fields, 2007). Overall, these coping processes may serve adaptive psychological and motivational functions in the face of age-related biological, social, and cognitive challenges (Rothermund & Brandtstadter, 2003).

It is also worth discussing that these different theoretical perspectives treat contextual factors (e.g., interpersonal aspects, type of coping task) quite differently. According to the reactivity hypothesis of disease, such an assessment is best made across these contexts; thus, the question focuses more on how generally reactive older adults are across situations. However, the approach of Levenson (2000) and Labouvie-Vief (2008) leaves room for the possibility that contextual factors may influence the success of self-regulatory strategies. This is reflected in work suggesting that age differences in the relevance of laboratory-based stressors may affect physiological reactivity. For instance, Kunzmann and Gröhn (2005) found that the use of age-relevant themes (e.g., loss of a loved one) in emotional film clips resulted in no age difference on indices of autonomic reactivity. Thus, the modeling of contextual factors is more relevant to the self-regulatory approach, although it can also inform disease risk models if assessments of exposure to such

situations are also obtained (i.e., does it occur frequently enough to influence disease risk).

One limitation of the present review is that due to the small number of studies, we were only able to examine a limited number of cardiovascular assessments. One assessment that may be particularly important in future work is respiratory sinus arrhythmia (RSA). There is some theoretical and empirical work suggesting that RSA (a noninvasive index of parasympathetic control of the heart) may be linked to self-regulatory capacity (Fabes & Eisenberg, 1997; Thayer & Lane, 2008). As a result, RSA may be of particular theoretical importance as a measure addressing these models. In this regard, aging tends to be associated with decreased resting parasympathetic control of the heart (DeMeersman, 1993). There were also a few studies that examined the link between age and RSA reactivity during stress: one study reported no age differences during emotional tasks (Boutcher & Stocker, 1996) and one found greater RSA withdrawal during stressful tasks (Uchino et al., 1999). Jennings and colleagues (1997) did not find any age differences in parasympathetic reactivity to stress, at least as indexed by a task known to elicit a vagal-mediated heart rate deceleration (i.e., anticipatory response to shooting task). However, in our longitudinal study, we also found that age predicted greater changes in parasympathetic withdrawal to stressful tasks over time (Uchino et al., 2005), which would be consistent with poorer self-regulatory capacity. Future research incorporating RSA into aging-reactivity work would produce valuable data on these theoretical perspectives.

CONCLUSIONS

In conclusion, we conducted a meta-analysis aimed at testing the predictions of several theoretical perspectives in the literature. Is aging associated with increased or decreased reactivity to emotionally evocative stimuli? Based on the more general age and physiological function literature, we argue that results of this review for the biological domain appear more consistent with the reactivity and disease and dynamic integration perspectives. However, this review represents just the first wave of research on this important question. More definitive answers to these questions will require further interdisciplinary work aimed at modeling the contexts (stress related or not), proposed theoretical mediators, more specific biological changes, and particular functions these differences might serve.

SUPPLEMENTARY MATERIAL

Supplementary material can be found at: <http://psychogerontology.oxfordjournals.org/>

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