HHS Public Access

Author manuscript

Biol Psychiatry Cogn Neurosci Neuroimaging. Author manuscript; available in PMC 2019 February 01.

Published in final edited form as:

Biol Psychiatry Cogn Neurosci Neuroimaging. 2018 February ; 3(2): 107–115. doi:10.1016/j.bpsc.2017.08.003.

Attentional Bias to Reminders of the Deceased as Compared to a Living Attachment in Grieving

Noam Schneck, PhD^{1,2,3}, Tao Tu, ME³, Christina A. Michel, BA^{1,2}, George A. Bonanno, PhD⁴, Paul Sajda, PhD³, and J. John Mann, MD^{1,2}

¹Division of Molecular Imaging and Neuropathology, New York State Psychiatric Institute, New York, NY

²Department of Psychiatry, Columbia University, New York, NY

³Department of Biomedical Engineering, Columbia University, New York, NY

⁴Department of Clinical Psychology, Teachers College, Columbia University, New York, NY

Abstract

Background—Grieving individuals demonstrate attentional bias towards reminders of the deceased *vs.* neutral stimuli. We sought to assess bias towards reminders of the deceased *vs.* a living-attachment figure and to evaluate similarities and differences in the neural correlates of deceased and living-related attention. We also sought to identify grief process variables associated with deceased-related attentional bias.

Methods—Twenty-five subjects grieving the death of a first-degree relative or partner within 14-months performed an emotional Stroop task, using words related to a deceased or a living attachment figure, and a standard Stroop task, to identify general selective attention, during functional magnetic resonance imaging (fMRI). Subjects rated word-sadness, complicated grief (CG) symptoms, depression severity, attachment style, emotional pain, non-acceptance, yearning and intrusions.

Results—We identified an attentional bias to deceased *vs.* living-related words, independent of age, depression severity/history, loss-type, word-sadness, medication use and time since loss. Attentional bias correlated with CG severity and intrusive thinking. A conjunction analysis identified joint activation in fusiform gyrus, posterior cingulate and temporal parietal junction across living and deceased-related attention *vs.* general selective attention. Insecure-avoidant attachment style correlated with decreased engagement of this network in deceased-related attention.

Address all correspondence and requests for reprints to: Noam Schneck Ph.D., NYSPI, 1051 Riverside Drive, New York, NY 10032. Tel#: 240-393-9119, schneck@nyspi.columbia.edu.

Financial Disclosures

Dr. Mann receives royalties for commercial use of the C-SSRS from the Research Foundation for Mental Hygiene. Dr. Sajda is the majority owner and Chairman of the Board of Neuromatters LLC, a brain computer interface neuromarketing and gaming company. All other authors report no biomedical financial interests or potential conflicts of interest.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Conclusions—We have demonstrated an attentional bias to reminders of the deceased *vs.* a living attachment in grieving. Overlapping neural circuits related to living and deceased-related attention suggests that the bereaved employ similar processes in attending to the deceased as they do in attending to the living. Deceased-related attentional bias appears to be linked primarily to intrusive thinking about the loss.

Keywords

Grieving; Attention Bias; Attachment; Fusiform; Intrusive-thinking; Complicated Grief

Introduction

During the first year following the loss of a loved one, reminders of the deceased occupy attention and provoke thinking about the loss (1). This salience has been operationalized as attentional bias, the unintentional and disproportionate allocation of attention to reminders of the deceased *vs.* neutral stimuli, and related to the pathological grief response known as complicated grief (CG)(2–5).

It remains unclear if attentional bias to reminders of the deceased *vs.* neutral stimuli reflects a bias to the deceased specifically or a more general process of emotional attachment seeking. Close attachment relationships evoke attention regardless of whether they are living or deceased (6, 7). Attentional biasing towards attachment-reminders may also reflect attention towards the predominant emotions related to that attachment (8) such as sadness in the case of grieving. We therefore sought to demonstrate a bias to reminders of the deceased as compared to a living attachment and to demonstrate the independence of this bias from sadness evoked by reminders of the deceased and living attachments.

Prior studies have correlated attentional bias to CG (3, 5). However, CG is an amalgam of cognitive, emotional and functional processes related to grieving (9). Intrusive thinking, non-acceptance, yearning and emotional pain are all core components of CG(10). People who don't accept the loss, who lack control over the contents of their mind or are overcome with pain or yearning may all demonstrate greater bias to the deceased. It is unknown which, if any, of these components demonstrates a specific relationship with attentional bias. For this reason, we tested the role of all four grief process variables, as well as CG, in attentional bias.

We next sought to determine the degree of similarity or difference in the processes underlying attention to the deceased and to a living attachment. Freud's grief-work hypothesis states that the bereaved must sever their connections with the deceased during grieving in a process of decathexis that is unique to loss and grieving (11). By contrast, the attachment theory of grieving suggests that the bereaved reform and restructure their relationship with the deceased so that it may continue to exist in the post-death reality (12–17). Accordingly, a relationship with the deceased may be maintained in much the same way that a relationship with a living attachment exists (15). This latter perspective would imply greater similarity between attention to the deceased and attention to living attachments.

Prior fMRI studies have shown increased rostral anterior cingulate and orbital frontal cortex engagement in deceased *vs.* neutral attention in bereaved *vs.* non-bereaved subjects as well as altered frontal-limbic connectivity related to intrusive thinking in grieving (2, 4). These findings suggest unique neural substrates for deceased-related attention. However, the comparison of neural activity across deceased and neutral conditions may correspond to processing emotional attachments in general. It remains unclear if the bereaved would process living and deceased attachments in a similar or different way. Therefore, we used functional magnetic resonance imaging (fMRI) to evaluate common or separate neural circuitry underlying deceased *vs.* living-related attention. The continuing bonds, as compared to decathexis, model has gained significantly greater research support (12–17). We therefore expected to find greater similarity rather than difference in neural correlates of living and deceased-related attention.

We administered an emotional (8) and cognitive (18) Stroop task during fMRI to grieving subjects. The emotional conditions comprised deceased-related words and living-related words. The emotional Stroop task measures attentional bias to reminders of the deceased because it pits task instructions (i.e. respond as fast as possible) against the tendency to focus on reminders of the deceased or living attachment, which would slow reaction time. It is therefore more likely to tap into control impairments characteristic of CG. The cognitive Stroop allows for the comparison between neural activity associated with attachment-related attention in the deceased and living-related conditions and general selective attention.

Methods

Subjects

We recruited 25 people bereaved of a first-degree relative or partner within the past 3 to 14-months. Subjects were between 18 and 65 years old, had normal color vision and spoke English as a first language. Subjects were recruited as part of a broader study of suicide bereavement. Recruitment was done through social media websites and contacting people listed as relatives in obituaries. 19 of these 25 were bereaved of a loss by suicide while the others were bereaved of a non-suicide death. While time since loss ranged from 3–14 months there were no subjects who were interviewed or scanned during the 12th month. This was done to avoid anniversary reactions.

All subjects were medically healthy as determined by medical history, examination and standard blood and urine tests. Exclusion criteria were manic episode within the past year, current substance use disorder (i.e. met criteria within past six months), current obsessive-compulsive disorder, lifetime schizophrenia or schizoaffective disorder assessed with the Structured Clinical Interview for DSM-IV Axis I (SCID I)(19). Psychiatric medication use was required to be stable for two weeks prior to scanning. The New York State Psychiatric Institute IRB approved this study and all subjects gave written informed consent.

Procedure

Subjects underwent a pre-scan interview, an MRI scan and then a post-scan interview. Both interviews always occurred within one week of the scan. During the pre-scan interview

subjects presented a living person with whom they have a similar relationship as they did with the deceased. Subjects provided 15 deceased and 15 living-related words. Word valence was rated as: 1= very sad, 2=sad 3=neutral, 4=happy and 5=very happy. To produce a sadness rating, emotion ratings were recoded as follows: 4,5=0; 3=1; 2=2 and 1=3. During the post scan interview subjects completed all structured interviews and questionnaires.

Measures

CG severity was measured with the Inventory for Complicated Grief (1, 20) (Cronbach's $\alpha=0.85$), which consists of 19-likert type items measuring frequency of complicated grief symptoms on a scale of 0=never to 4=always. Yearning was measured by a single item asking subjects how much they yearn for their loss on a scale of 1–10 with 10 being the most (4, 21). Emotional pain and non-acceptance were measured through the emotional pain and non-acceptance factors of the Texas Revised Inventory of Grief (TRIG-EP, $\alpha=0.75$; TRIG-NA, $\alpha=0.75$) (22). Intrusive thinking was measured with the intrusion subscale of the Impact of Event Scale-Revised IES-I ($\alpha=0.74$)(23). The IES-R is a 21 item scale measuring distress related to symptoms of post-traumatic stress in the past seven days on a scale of 0=Not at all to 4=Extremely. Depression severity was measured with the Center for Epidemiological Studies Depression short scale (CESD, ((24)) ($\alpha=0.83$) and the Beck Depression Inventory (BDI, (25)) ($\alpha=0.83$). Avoidant attachment style was measured with the avoidant-attachment subscale of the Adult Attachment Scale (26), on which higher scores (0–7) indicate more avoidant attachment. This scale was introduced after the start of the study and only completed by 17 subjects. The total count of major depressive episodes was determined as part of the SCID interview. Psychiatric medication use was coded as a binary variable indicating the presence or absence of current medication use

Stroop Task

During the scan, subjects completed four runs of a cognitive and emotional Stroop task. Each run consisted of four blocks of words: deceased, living, congruent and incongruent. The design for the Stroop task is presented in Figure 1. In all blocks, subjects were presented with words and instructed to identify the color of the word font as fast as possible using a right-hand held button box. Training was conducted until subjects reached 100% accuracy and speed of color-button pressing dropped under one second for ten consecutive practice trials. All 15 words were presented for 1.5 seconds and followed by a randomly jittered fixation cross averaging two seconds. A ten-second fixation cross was presented in between each block. Word presentation and color pairings were randomized within a block and block order was permuted across runs.

Imaging

Blood-oxygen-level dependent (BOLD) images were acquired on a GE 3-T scanner parallel to the anterior commissure-posterior commissure (AC-PC) line with a T2*-weighted EPI sequence of 45 contiguous slices (TR=2000ms, TE=25ms, flip angle = 77, FoV=192 × 192mm,) of 3mm thickness and 3×3 in-plane resolution. Structural images were acquired with a T1-weighted SPGR sequence recording 256 slices at a slice thickness of 1mm and in-plane resolution of 1×1mm.

Preprocessing

Preprocessing included slice time correction, motion correction, 120-second high-pass filter, bias field correction, skull stripping and smoothing with a Gaussian kernel of 6mm FWHM. Functional images were registered to structural images with 7-degrees of freedom and then structural images were warped to the standard MNI space using a 12-degree affine registration implemented in FLIRT (27). 7 degrees of freedom for the initial warp provided better registration than 6-degrees. Originally a nonlinear warp was also applied in FNIRT(28). However, visual inspection revealed that this registration failed for one subject and thus the linear registration was used.

Attentional Bias

Reaction time (RT) data was analyzed using SPSS (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.) RTs were log transformed to reduce the effects of outliers. Linear mixed models included a subject specific random intercept and run number (1–4) and trial number (1–15) as fixed covariates. Error trials were excluded.

To identify an attentional bias to deceased relative to living-related words we entered condition type (i.e. deceased-related, living-related) as a fixed effect predicting RT. This analysis was repeated while covarying for word-evoked sadness, age, current depression symptom severity (BDI and CES-D), psychiatric medication use and the number of prior major depressive episodes.

Attentional Bias and Grief Processing

We sought to evaluate the respective relationships between attentional bias and grief process variables of: emotional pain (TRIG-EP), non-acceptance (TRIG-NA), yearning (1–10 rating) and intrusive thinking (IES-I) as well as general CG severity. For each variable a separate mixed effects model was calculated to test the interaction of condition type (deceased, living) and the grief process variable on RT. Significance threshold was set to $p < 0.01$ to Bonferroni correct for five analyses.

Neural Circuitry of Attentional Bias

Blood oxygen level dependent (BOLD) signal was analyzed using FSL (29). We were primarily interested in determining whether separate or similar neural systems exist for deceased and living-related attention. To do this we first sought to identify neural signal corresponding to deceased and living-related attention independently. Simply identifying activity associated with deceased and living-related trials might yield clusters involved in reading the words but not necessarily *attending* to them. We therefore modeled the length of the presentation of each word at each trial (i.e. 1.5s) to account for activation relating to reading and interpreting Stroop words. A trial-level parametric regressor was then used to model RT. The first level fMRI analysis identified the correlation between each voxel's BOLD activity and *attention* to the deceased or living figure as measured by the trial-level RT regressor. Subject level fixed-effects analyses identified parameter estimates for the relationship between voxelwise BOLD activity and RT for each person condition (i.e. Deceased-related (BOLD X RT), Living-related (BOLD X RT) across runs.

We next sought to determine the degree of similarity in neural processing of deceased and living-related attention. A lack of difference between two conditions or simply calculating the summed average of two conditions does not indicate significant overlap in neural activity underlying both conditions (30). Significance of activation across two conditions can be determined with a conjunction analysis (30), which identifies voxels associated with condition A AND B as compared to the variability A and B. We therefore assessed the conjunction of voxels whose BOLD activity correlated with RT across both living and deceased-related trials.

However, there are two confounds inherent to the approach described above. 1) Both equations for deceased and living-related attention identify activity based on RT. Without comparing to another RT based contrast we would simply identify neural activity associated with pushing buttons. 2) Both of these contrasts identify activity associated with either deceased or living-related attention. However, it is likely that such attentional activity also incorporates general selective attention that is not specific to attachment processing.

To account for button pressing we controlled for BOLD correlation with RT to deceased (Deceased-related (BOLD X RT)>Congruent (BOLD X RT) and living-related trials (Living-related (BOLD X RT)> Congruent (BOLD X RT). To account for general selective attention, we identified clusters which were significantly more active during incongruent color-word trials as compared to congruent color-word trials. Notably, all words across both incongruent and congruent trials have the same meaning. For this reason, we did not need to incorporate RT into the contrast identifying general selective attention and therefore identified voxel clusters involved in general selective attention as follows: (Incongruent BOLD>Congruent BOLD). As a result, the total contrast identifying deceased and living-related attention while accounting for voxels associated with general attentional interference and for button pressing activity was: for deceased ((Deceased-related (BOLD X RT)> congruent (BOLD X RT))> (Incongruent BOLD>Congruent BOLD)) and for living ((Living-related (BOLD X RT)> Congruent (BOLD X RT))> (Incongruent BOLD>Congruent BOLD)). Nuisance regressors modeled out error trials and standard six-degree motion regressors.

Separate two-sided mixed effects analyses were implemented in FSL's FLAME (29) to identify voxel clusters significantly associated with RT for deceased and living-related trials (voxel- $p < 0.001$, cluster- $p < 0.05$). To compare activity between deceased and living-related attention the contrasts described above were compared with a within subjects t-test implemented in FSL (voxel- $p < 0.001$, cluster- $p < 0.05$, corrected). To identify common activity in these networks we employed a conjunction analysis (30) (voxel- $p < 0.001$, cluster- $p < 0.05$, corrected). Regional localizations were identified using the Harvard-Oxford Cortical and Subcortical atlases (31) applied to the Montreal Neurological Institute 152 standard brain template, Brodmann areas were identified using the Talairach Atlas(32).

Results

Table 1 describes the demographic and clinical characteristics of the sample. On average the sample contained a considerable degree of grief intensity with a wide range across levels of

severity (average ICG=27.04, Range=49). Post-hoc analyses confirmed that deceased and living-related lists did not have significant differences in word length, part of speech or language frequency (Supplemental Information, Supplemental Table 1).

Attentional Bias

Errors were more common on deceased vs. living-related ($\chi^2=6.52$, $p=0.01$) and incongruent vs. congruent ($\chi^2=23.01$, $p<0.01$) trials. An attentional bias was evidenced by slower RT to deceased vs. living related words ($B=0.012$, $t_{2831}=2.73$, $p<0.006$, 95% CI=0.003–0.213, Cohen's $d=0.85$) and to incongruent vs. congruent words ($B=0.19$, $t_{2754}=19.43$, $p<0.001$, 95% CI=0.177–0.1216, Cohen's $d=6.47$) (Table 2). The bias to deceased-related words persisted after controlling for the effect of time since loss, complicated grief severity, age, CESD/BDI, number of prior major depressive episodes, suicide-loss, and medication use on response time (Table 2). Supplemental table S2 presents raw response data from the Stroop task.

Bias to Deceased vs. Sadness

42% of deceased-related and 16% of living-related trials used words with a sadness rating of sad or very sad. Estimated marginal means of sadness were: deceased-related (1.24(0.08)), living-related (0.59(0.08)). Deceased-related words were rated as sadder than living-related words ($t_{1748}=16.67$, $p<0.001$). Without modeling condition type (i.e. deceased and living-related trials) we observed a relationship between RT and trial-level sadness rating ($B=0.005$, $t_{2841}=2.42$, $p=0.01$, 95% CI=0.0009–0.009). When modeling condition type and sadness rating, condition remained a significant predictor of RT ($B=0.009$, $t_{2831}=2.08$, $p=0.03$, 95% CI=0.0005–0.0188) while sadness rating did not ($B=0.003$, $t_{2841}=1.66$, $p=0.09$, 95% CI=–0.0006–0.008).

Grief Process Variables

Emotional pain, non-acceptance, yearning, intrusion and ICG scores were all correlated with each other (Supplemental Table S3). Despite this correlation structure only intrusive thinking and ICG scores displayed an interaction effect with condition (living, deceased) on RT after correcting for multiple comparisons (Figure 2, Table 3). Subjects with more intrusive thinking and higher CG severity displayed significantly greater attentional bias to deceased vs. living-related words (Figure 2). Intrusive thinking was positively correlated with RT to deceased-related trials and less so to living-related trials (Table 3). Emotional pain, non-acceptance and yearning did not significantly interact with condition (living, deceased) as predictors of RT (Table 3). No grief process variables exhibited a main effect on RT across conditions. Intrusive thinking did not moderate the relationship between incongruent vs. congruent condition type and RT ($B=0.001$, $t_{2755}=0.31$, $p=0.76$, 95% CI=–0.01–0.01), demonstrating the specificity of this finding to deceased-related attention.

Neural Circuitry of Deceased and Living-Related Attention

Activity in lateral occipital cortex, fusiform gyrus and temporal parietal junction correlated with RT to reminders of the deceased. Activity in similar clusters as well as a range of limbic and frontal regions correlated with RT to reminders of the living (Supplemental

Figure S1, Tables S4 and S5). However, direct comparison of neural correlates of deceased vs. living-related RT revealed no significant differences. This lack of difference persisted when using a more lenient threshold as well (voxel- $p < 0.05$ and cluster- $p < 0.1$).

A conjunction analysis identified common regions of activation across deceased and living-related conditions. This analysis identified activity in lateral occipital lobe, right temporal parietal junction (rTPJ), occipital and temporal fusiform gyri and posterior cingulate associated with both deceased and living-related attention (Figure 3A, Table 4, for full list of regions). All of the above analyses controlled for button pressing (BOLD X Congruent RT) as well as general selective attention (Incongruent BOLD > Congruent BOLD) as described above.

To determine the potential role of these regions in attachment processing we tested the correlation between insecure-avoidant attachment style and average activity in the conjoint network of regions associated with living and deceased related attention during deceased-related trials. Subjects with a more secure rather than avoidant attachment style displayed significantly greater activation of the deceased and living-related neural circuitry during deceased-related trials ($r = -0.51$, $p = 0.03$, Figure 3B).

We tested the correlation between time since loss and engagement of the conjoint deceased and living-related attention network during deceased related trials. According to the deathecis theory, engagement of the conjoint network should decrease over time as living and deceased-related processing become less similar. According to the continuing bonds model, engagement of the conjoint network should maintain over time as the deceased continues to be processed in a similar way to a living attachment. Our findings were consistent with the latter theory showing no correlation between conjoint activity during deceased-related trials and time since loss ($r = -0.14$, $p = 0.49$).

General Selective Attention

A number of clusters in frontal regions showed greater activity during incongruent vs. congruent trials: left inferior frontal gyrus (BA 9), middle frontal gyrus (BA 6), bilateral superior frontal gyrus (BA 6) and frontal pole (BA 10) (Supplemental Figure S2, Supplemental Table S6). There were no regions that displayed greater activity for congruent vs. incongruent blocks.

Discussion

Grieving individuals displayed an attentional bias to reminders of a deceased as compared to living attachment independently of sadness evoked by deceased-related words, depressive symptoms and history, medication use, age and time since loss. Attentional bias was associated with intrusive thinking and general CG severity, but not emotional pain, non-acceptance and yearning. fMRI findings suggested more similarity rather than difference in the brain regions involved in deceased and living-related attention as compared to general selective attention.

Prior studies have related impaired grieving (i.e. CG) to biased deceased *vs.* neutral attention (3, 5). To date, it remained unclear if CG involved general impairment in control over emotional attachment-related attention or a specific deceased-related attentional bias. We now show that a specific bias to the deceased *vs.* a living attachment exists independently of sadness evoked by reminders of the loss. While general emotion regulation remains a relevant and important part of the grief process, our findings present deceased-related attention specifically as a unique and significant element of the grief process as well.

The bias to reminders of the deceased *vs.* a living attachment does not appear to be driven by emotional components of grieving such as pain, word-sadness, or yearning. Intrusive thinking describes a lack of control over salient thoughts, but does not explain what causes deceased-related thoughts to be salient. Once accounting for sadness, pain and yearning, the major difference between reminders of the deceased and living-attachment is the memory of the death itself. The memory of the death may drive attention towards the deceased as compared to a living attachment. Along these lines, recent effective treatments for CG have emphasized the importance of reviewing the death event in detail potentially habituating attentional biases to the death (33, 34). One of the tasks of grieving may therefore be reducing the degree that attention is biased to memories of the death.

We also sought to determine whether deceased and living-related attention represent unique or similar processes. In prior studies, rostral anterior cingulate engagement and prefrontal-amygdala connectivity in deceased *vs.* neutral attention differentiated bereaved and non-bereaved participants and correlated with intrusions respectively (2, 4). Our findings diverge, showing greater similarity rather than difference in neural processing of deceased *vs.* living-related attention. The contrast between attention to deceased-related and neutral stimuli invoked in prior work may therefore display shifts in general emotional and attachment processes occurring in grieving rather than a deceased specific neural substrate. However, differences between our findings and prior studies may also reflect differences in the samples (suicide bereaved, 3 to 14-months post-loss), tasks (i.e. counting Stroop, color-Stroop) and analyses (event or block design, cluster forming thresholds).

Our fMRI neuroanatomical data revealed significant conjoined rather than differential activity associated with attention to deceased and living-related stimuli. This activity was located in: lateral occipital cortex and the fusiform gyrus, part of the face or person processing networks (35); right temporal parietal junction (rTPJ), which has been linked to theory of mind (36); and posterior cingulate a part of the default mode network (37). Notably these neural findings were unique from a set of regions associated in this study and in others with general selective attention (38). The similarity between neural correlates of deceased and living-related attention suggests that to some extent the bereaved attend to the deceased the same way that they attend to a living attachment. This is consistent with the continuing bonds theory of grieving which suggests a continued evolving relationship between the bereaved and the deceased (12–17).

People with insecure-avoidant attachment styles, who invest less emotional connection in their relationships, showed reduced neural activity in the conjoined deceased and living-related attention network. The neural activity identified in this study may correspond to the

emotional connection between the bereaved and their living and deceased attachments. Nevertheless, the correlation between neural activity and attachment style may also reflect separate processes (i.e. memory) engaged more or less by insecurely attached people. Future studies should incorporate a non-attachment other person condition to more definitively identify the role of attachment processing in deceased-related attention.

Limitations

Future studies with larger sample sizes could better parse the effect of suicide bereavement vs. general grieving on attentional bias. Similarly, this sample had a limited number of males and could not assess the role of gender. Furthermore, the lack of association between emotional pain and yearning and attentional bias may also reflect limited power due to a smaller sample size. We interpret attentional bias as deriving from non-emotional sources, having controlled for pain, sadness and yearning. However, we did not measure anger, resentment or bitterness, which may also contribute to bias.

Future Work

Future work can test the causal role of attentional bias to the deceased on grief outcomes. Specifically computerized attentional bias interventions can be implemented to foster greater control over thoughts of loss. Future studies can also directly measure memories of the death to determine if they play a role in attentional bias and grief resolution. Finally, incorporation of a non-attachment control figure would better delineate the degree that attachment processing contributes to underlying deceased and living-related attention.

Conclusions

We demonstrated an attentional bias to the deceased vs. a living attachment figure that was associated with greater intrusive thinking and general CG severity, but not emotional components of grief such as sadness, pain and yearning. These findings suggest that memories of the death itself may drive bias to the deceased vs. a living figure. Despite the presence of a bias to deceased vs. a living figure, neural findings indicated similarity in the underlying processes subserving deceased and living-related attention. Taken together, these findings suggest that one of the tasks of grieving is to employ control over deceased-related thoughts and to maintain a continuing bond with the deceased similar to that which exists with a living attachment.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

This study was generously funded by a Distinguished Investigator Grant (DIG-0-163-12) (JJM) and a Young Investigator Grant (YIG-0-215-13) (NS) from the American Foundation for Suicide Prevention. NS was supported by a National Institute of Mental Health T32 Training Grant in Anxiety and Related Disorders (T32-MH020004-16).

References

1. Zisook S, Shear K. Grief and bereavement: what psychiatrists need to know. *World Psychiatry*. 2009; 8:67–74. [PubMed: 19516922]
2. Arizmendi B, Kaszniak AW, O'Connor MF. Disrupted prefrontal activity during emotion processing in complicated grief: An fMRI investigation. *Neuroimage*. 2016; 124:968–976. [PubMed: 26434802]
3. Maccallum F, Bryant RA. Attentional bias in complicated grief. *J Affect Disord*. 2010; 125:316–322. [PubMed: 20483163]
4. Freed PJ, Yanagihara TK, Hirsch J, Mann JJ. Neural mechanisms of grief regulation. *Biol Psychiatry*. 2009; 66:33–40. [PubMed: 19249748]
5. O'Connor MF, Arizmendi BJ. Neuropsychological correlates of complicated grief in older spousally bereaved adults. *J Gerontol B Psychol Sci Soc Sci*. 2014; 69:12–18. [PubMed: 23551907]
6. Liu Y, Ding Y, Lu L, Chen X. Attention Bias of Avoidant Individuals to Attachment Emotion Pictures. *Sci Rep*. 2017; 7:41631. [PubMed: 28128347]
7. Vandevivere E, Braet C, Bosmans G, Mueller SC, De Raedt R. Attachment and children's biased attentional processing: evidence for the exclusion of attachment-related information. *PloS one*. 2014; 9:e103476. [PubMed: 25061662]
8. Williams JM, Mathews A, MacLeod C. The emotional Stroop task and psychopathology. *Psychol Bull*. 1996; 120:3–24. [PubMed: 8711015]
9. Prigerson HG, Shear MK, Jacobs SC, Reynolds CF 3rd, Maciejewski PK, Davidson JR, et al. Consensus criteria for traumatic grief. A preliminary empirical test. *Br J Psychiatry*. 1999; 174:67–73. [PubMed: 10211154]
10. Shear MK, Simon N, Wall M, Zisook S, Neimeyer R, Duan N, et al. Complicated grief and related bereavement issues for DSM-5. *Depress Anxiety*. 2011; 28:103–117. [PubMed: 21284063]
11. Freud, S., Rieff, P. 1st Touchstone paperback ed. *General psychological theory: papers on metapsychology*. New York: Touchstone; 2008.
12. Shear K, Shair H. Attachment, loss, and complicated grief. *Dev Psychobiol*. 2005; 47:253–267. [PubMed: 16252293]
13. Bowlby, J. *Attachment and loss*. New York: Basic Books; 1980.
14. Klass, D., Silverman, PR., Nickman, SL. *Continuing bonds: new understandings of grief*. Washington, DC: Taylor & Francis; 1996.
15. Schuchter, SR., Zisook, S. *The Course of Normal Grief*. Cambridge England; New York, NY, USA: Cambridge University Press; 1993.
16. Klass D. The deceased child in the psychic and social worlds of bereaved parents during the resolution of grief. *Death Stud*. 1997; 21:147–175. [PubMed: 10169689]
17. Bonanno GA, Kaltman S. Toward an integrative perspective on bereavement. *Psychol Bull*. 1999; 125:760–776. [PubMed: 10589301]
18. Stroop, JR. *Studies of interference in serial verbal reactions* [Ph D]. Nashville, Tenn: George Peabody College for Teachers; 1935.
19. First, M., Spitzer, R., Gibbon, M., Williams, J. *Structured Clinical Interview for DSM-IV Axis I Disorders (SCID-I/P, Version 2.0)*. New York: Biometrics Research Dept., New York State Psychiatric Institute; 1995.
20. Prigerson HG, Maciejewski PK, Reynolds CF 3rd, Bierhals AJ, Newsom JT, Fasiczka A, et al. Inventory of Complicated Grief: a scale to measure maladaptive symptoms of loss. *Psychiatry Res*. 1995; 59:65–79. [PubMed: 8771222]
21. O'Connor MF, Wellisch DK, Stanton AL, Eisenberger NI, Irwin MR, Lieberman MD. Craving love? Enduring grief activates brain's reward center. *Neuroimage*. 2008; 42:969–972. [PubMed: 18559294]
22. Fetterman A, Holland JM, Brown PJ, Thompson LW, Gallagher-Thompson D. Factorial validity of the Texas Revised Inventory of Grief-Present scale among bereaved older adults. *Psychol Assess*. 2010; 22:675–687. [PubMed: 20822280]

23. Baumert J, Simon H, Gundel H, Schmitt C, Ladwig KH. The Impact of Event Scale--Revised: evaluation of the subscales and correlations to psychophysiological startle response patterns in survivors of a life-threatening cardiac event: an analysis of 129 patients with an implanted cardioverter defibrillator. *J Affect Disord.* 2004; 82:29–41. [PubMed: 15465574]
24. Irwin M, Artin KH, Oxman MN. Screening for depression in the older adult: criterion validity of the 10-item Center for Epidemiological Studies Depression Scale (CES-D). *Arch Intern Med.* 1999; 159:1701–1704. [PubMed: 10448771]
25. Beck AT, Ward CH, Mendelson M, Mock J, Erbaugh J. An inventory for measuring depression. *Arch Gen Psychiatry.* 1961; 4:561–571. [PubMed: 13688369]
26. Fraley R, Davis K. Attachment formation and transfer in young adults' close friendships and romantic relationships. *Personal Relationships.* 1997; 4:131–144.
27. Jenkinson M, Bannister P, Brady M, Smith S. Improved optimization for the robust and accurate linear registration and motion correction of brain images. *Neuroimage.* 2002; 17:825–841. [PubMed: 12377157]
28. Andersson, JLR MJ a SMS. FMRIB technical report TR07JA2. 2007. Non-linear registration, aka Spatial normalisation.
29. Woolrich MW, Jbabdi S, Patenaude B, Chappell M, Makni S, Behrens T, et al. Bayesian analysis of neuroimaging data in FSL. *Neuroimage.* 2009; 45:S173–186. [PubMed: 19059349]
30. Nichols T, Brett M, Andersson J, Wager T, Poline JB. Valid conjunction inference with the minimum statistic. *Neuroimage.* 2005; 25:653–660. [PubMed: 15808966]
31. Desikan RS, Segonne F, Fischl B, Quinn BT, Dickerson BC, Blacker D, et al. An automated labeling system for subdividing the human cerebral cortex on MRI scans into gyral based regions of interest. *Neuroimage.* 2006; 31:968–980. [PubMed: 16530430]
32. Lancaster JL, Woldorff MG, Parsons LM, Liotti M, Freitas CS, Rainey L, et al. Automated Talairach atlas labels for functional brain mapping. *Hum Brain Mapp.* 2000; 10:120–131. [PubMed: 10912591]
33. Boelen PA, Prigerson HG. The influence of symptoms of prolonged grief disorder, depression, and anxiety on quality of life among bereaved adults. *European archives of psychiatry and clinical neuroscience.* 2007; 257:444–452. [PubMed: 17629728]
34. Shear MK. Complicated grief treatment: the theory, practice and outcomes. *Bereave Care.* 2010; 29:10–14. [PubMed: 21852889]
35. Nagy K, Greenlee MW, Kovacs G. The lateral occipital cortex in the face perception network: an effective connectivity study. *Front Psychol.* 2012; 3:141. [PubMed: 22593748]
36. Krall SC, Rottschy C, Oberwelland E, Bzdok D, Fox PT, Eickhoff SB, et al. The role of the right temporoparietal junction in attention and social interaction as revealed by ALE meta-analysis. *Brain structure & function.* 2015; 220:587–604. [PubMed: 24915964]
37. Leech R, Sharp DJ. The role of the posterior cingulate cortex in cognition and disease. *Brain: a journal of neurology.* 2014; 137:12–32. [PubMed: 23869106]
38. Peterson BS, Skudlarski P, Gatenby JC, Zhang H, Anderson AW, Gore JC. An fMRI study of Stroop word-color interference: evidence for cingulate subregions subserving multiple distributed attentional systems. *Biol Psychiatry.* 1999; 45:1237–1258. [PubMed: 10349031]

Figure 1. Design of emotional and cognitive Stroop task

Stimuli were presented using a mixed block-event design presenting words of each condition in a unified block with inter-trial jitter allowing for trial level analyses. Deceased and living-related trials presented reminders of the deceased and a living attachment figure provided a week before the scan by the subject. Color congruent and incongruent trials comprised standard Stroop conditions.

Figure 2. Intrusive thinking interacts with condition type in predicting reaction time

Simple slopes display the relationship between deceased and living-related condition and average log transformed reaction time (log-RT) across high and low levels of grief process variables as well as complicated grief severity. For the sake of presentation high and low intrusive thinking, emotional pain, non-acceptance, yearning and complicated grief are presented as above and below respective medians of intrusions=2.25, emotional pain=3.6, non-acceptance 3.33, yearning=8, complicated grief (ICG)=26. The difference between reaction time to deceased and living-related conditions is greater for those with high as compared to low intrusive thinking. No such effect is observed for other process variables.

Figure 3.

Figure 3A. Conjunction analysis of deceased and living-related attention. Activity in lateral occipital cortex, fusiform gyrus (XYZ=54,31,35), temporal parietal juncture, (XYZ=17,34,30) and posterior cingulate (XYZ=46,39,44) is observed. All analyses thresholded at voxel- $p < 0.001$, cluster- $p < 0.05$ and controlled for button pressing, general selective attention and word reading. **3B.** Subjects with a more secure as opposed to avoidant attachment style showed greater engagement of the conjoint deceased and living-related attention network during deceased related trials. Engagement of conjoint network during deceased related trials corresponds to subject level z-score of the correlation between BOLD activity in the conjunction mask and deceased-related attention.

Table 1

Sample Description

Demographic and Clinical Variables	M	SD	Range
Age	45	13	19–64
Months Since Loss	7.96	4.04	3–14
ICG	27.04	12.99	1–50
CES-D	1.64	0.45	1–2.64
BDI	8.45	9.56	0–31
Education years	16.28	1.96	12–20
Emotional Pain	3.36	0.81	1.6–4.6
Intrusive Thoughts	2.41	0.72	1.25–3.88
Non-Acceptance	2.86	1.02	1–4.33
Yearning	7.6	2.53	2–10
Household Income	N	%	
>\$70,000	15	60	
\$60,000–\$69,000	5	20	
\$50,000–\$59,000	1	4	
\$30,000–\$39,000	4	16	
Prior Depressive Episodes			
0 Episodes	11	44	
1 Episode	7	28	
2 Episodes	4	16	
3 Episodes	2	8	
5 Episodes	1	4	
Married	11	44	
Males	2	8	
Psychiatric Medication Use	10	40	

ICG= Inventory for Complicated Grief, CES-D= Center for Epidemiological Studies Depression, BDI=Beck Depression Inventory. Household income was coded with five interval levels of >\$70,000, \$60–\$69,000, \$50–\$59,000, \$40,000–\$49,000, and \$30–\$39,000. Psychiatric medication use was coded as a binary variable corresponding to whether or not a subject was currently using a psychiatric medication.

Table 2

Mixed Effect Models Identifying Attentional Bias

	<i>B</i>	S.E.	<i>df</i>	<i>t</i>	<i>p</i>	95% CI
Deceased vs. Living	0.012	0.004	2831	2.73	0.006	0.003–0.213
Incongruent vs. Congruent	0.197	0.010	2754	19.43	<0.001	0.177–0.121

Model Including Covariates						
	<i>B</i>	S.E.	<i>df</i>	<i>t</i>	<i>p</i>	95% CI
Deceased vs. Living	0.013	0.004	2477	2.81	0.005	0.004–0.022
Age	0.001	0.001	13	0.993	.339	–0.001–0.003
Time since loss	0.006	0.006	13	1.008	.332	–0.007–0.021
Suicide loss	0.059	0.044	13	1.330	.206	–0.037–0.155
ICG score	–0.001	0.002	13	–0.363	.722	–0.006–0.004
Medication use	0.055	0.035	13	1.544	.147	–0.022–0.133
CES-D score	0.048	0.067	13	0.708	.491	–0.098–0.194
BDI score	–0.006	0.002	13	–2.999	.010	–0.011–0.001
Previous MDEs	0.007	0.014	13	0.487	.634	–0.024–0.038

Covariate Effects		
Parameter	Estimate	S.E.
Residual	0.014	0.004
Subject	0.003	0.001
Run Number	0.012	0.001
Trial Number	<0.001	<0.001

Initial models tested the effect of deceased vs. living condition and incongruent vs. congruent condition on log transformed response times (log-RT). An additional model assessed the effect of deceased vs. living condition on log-RT while accounting for covariates. All models included random effects for subject and fixed effects for run, and trial number. ICG=Inventory for Complicated Grief, Medication=Bindyr score coding psychiatric medication use, CES-D= Center for Epidemiological Studies Depression, BDI=Beck Depression Inventory. MDE=major depressive episode.

Table 3
Mixed Effect Models Identifying Interactions of Grief Process Variables with Attentional Bias

	<i>B</i>	S.E.	<i>df</i>	<i>t</i>	<i>p</i>	95% CI	Partial- r^2
Intrusion							
Interaction	0.017	0.006	2830	2.71	0.006 [/]	0.004–0.029	
Main Effect	0.037	0.022	23	1.68	0.105	–0.008–0.082	
Deceased Trial RT	0.053	0.023	23	2.33	0.02	0.006–0.101	0.26
Living Trial RT	0.037	0.022	23	1.67	0.10	–0.008–0.084	0.15
Pain							
Interaction	0.007	0.005	2830	1.37	0.16 [/]	–0.003–0.018	
Main Effect	0.012	0.215	23	0.56	0.57	–0.322–0.056	
Deceased Trial RT	0.019	0.022	23	0.86	0.39	–0.027–0.066	0.05
Living Trial RT	0.012	0.021	23	0.58	0.56	–0.031–0.056	0.03
Yearning							
Interaction	0.001	0.001	2830	1.00	0.31 [/]	–0.001–0.005	
Main Effect	0.001	0.006	23	0.28	0.77	–0.012–0.016	
Deceased Trial RT	0.003	0.007	23	0.51	0.62	–0.011–0.018	0.05
Living Trial RT	0.002	0.006	23	0.30	0.76	–0.012–0.016	0.03
Non-Acceptance							
Interaction	0.007	0.004	2830	1.79	0.07 [/]	–0.001–0.016	
Main Effect	0.008	0.169	23	0.47	0.64	–0.027–0.043	
Deceased Trial RT	0.015	0.017	23	0.87	0.39	–0.021–0.052	0.11
Living Trial RT	0.008	0.016	23	0.49	0.62	–0.026–0.043	0.05
ICG Score							

	<i>B</i>	S.E.	<i>df</i>	<i>t</i>	<i>p</i>	95% CI	Partial- r^2
Interaction	0.001	0.003	2830	2.97	0.003	0.003–0.001	
Main Effect	0.014	0.001	23	1.09	0.28	–0.001–0.004	
Deceased Trial RT	0.002	0.013	23	1.85	0.08	–0.003–0.005	0.18
Living Trial RT	0.001	0.001	23	1.09	0.28	–0.001–0.004	0.09

[†] Original P Values are presented but significance threshold was set to $p < 0.01$ to correct for five comparisons.

Interaction= Interaction of grief process variable with deceased and living condition on log transformed response times (log-RT). Main effect= The main effect of the grief process variable on response time across deceased and living-related conditions. Deceased Trial RT= Main effect for grief process variable on response time in deceased condition only. Living Trial RT= Main effect for grief process variable on response time in living condition only.

Table 4

Clusters conjointly associated with deceased and living-related attention

Region	#Voxels	Z-Score	X	Y	Z
Posterior Cingulate Gyrus	45	3.41	48	42	56
Cuneal Cortex	536	3.53	43	23	50
Intracalcarine Cortex	552	3.40	45	27	41
Inferior Lateral Occipital Cortex	14	3.22	17	32	42
Superior Lateral Occipital Cortex	1221	3.61	40	22	49
Lingual Gyrus	536	3.42	48	29	34
Middle Temporal Gyrus	31	3.34	17	35	40
Occipital Fusiform Gyrus	41	3.44	48	24	30
Occipital Pole	800	3.66	45	17	48
Precuneous Cortex	674	3.45	45	35	54
Supracalcarine Cortex	80	3.61	46	30	44
Temporal Occipital Fusiform Cortex	65	3.48	58	38	30