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Unraveling the Mystery of Music: Music as an Evolved Group Process

Chris Loersch
University of Colorado

Nathan L. Arbuckle
University of Ontario Institute of Technology

As prominently highlighted by Charles Darwin, music is one of the most mysterious aspects of human nature. Despite its ubiquitous presence across cultures and throughout recorded history, the reason humans respond emotionally to music remains unknown. Although many scientists and philosophers have offered hypotheses, there is little direct empirical evidence for any perspective. Here we address this issue, providing data which support the idea that music evolved in service of group living. Using 7 studies, we demonstrate that people's emotional responses to music are intricately tied to the other core social phenomena that bind us together into groups. In sum, this work establishes human musicality as a special form of social cognition and provides the first direct support for the hypothesis that music evolved as a tool of social living. In addition, the findings provide a reason for the intense psychological pull of music in modern life, suggesting that the pleasure we derive from listening to music results from its innate connection to the basic social drives that create our interconnected world.

Keywords: evolution, group processes, music, musical reactivity, social cognition

> Perhaps the safest thing to do [in contacting alien life] at the outset, if technology permits, is to send music. This language may be the best we have for explaining what we are like to others in space, with least ambiguity.
>
> —Lewis Thomas, *Lives of a Cell: Notes of a Biology Watcher*

When we hear music it moves us, both physically (Clayton, Sager, & Will, 2005; Janata, Tomic, & Haberman, 2012; Zatorre, Chen, & Penhune, 2007) and emotionally (Gabrielsson & Lindström Wik, 2003; Maslow, 1976). Together, these effects make listening to music highly rewarding (Blood & Zatorre, 2001) and cause us to seek out ways to expose ourselves to musical content. This is evidenced both by the billions of dollars spent purchasing recorded music (Recording Industry Association of America, 2011) and by the fact that we are obviously driven to embed ourselves in a musical world. It is common, for instance, for people to wake up to the sound of a radio-alarm, listen to music in their home on a personal stereo, turn on the car stereo while driving, play an iPod or other portable music device while walking outdoors, and listen to music on a computer while at work—all in a single day. In addition, the vast majority of coffee shops, restaurants, bars, clubs, stores, and recreation centers also play music, allowing it to flow unabated, regardless of venue. Furthermore, video entertainment, movies, television shows, and advertisements all pour additional music into our lives. In conjunction, these various sources create a world in which many individuals rarely leave the comfort of a musical environment.

Importantly, there is ample evidence that the pervasiveness of music is not simply a fad of current Western society. Instead, music appears to be a universal human phenomenon. For example, some form of music has been identified in every documented culture (Huron, 2001). Furthermore, the fossil record demonstrates that humans (and our close evolutionary relatives, the Neanderthal) have produced music for many millennia. To date, the oldest known musical instrument is a bone flute excavated from the Divje Babe site in Slovenia. Carbon dating shows that it is a minimum of 43,000 years old (Turk, 1997).

Unsurprisingly, such facts have drawn the interest of many scientists and philosophers. For example, Darwin (1874) famously stated,

> As neither the enjoyment nor the capacity of producing musical notes are faculties of the least use to man in reference to his daily habits of life, they must be ranked amongst the most mysterious with which he is endowed. (pp. 569–570)

Since that time, a multitude of individuals have weighed in on this mystery, all offering their own theories regarding the evolved function of human musicality. For example, it has been argued that music is a sexually selected trait (e.g., Darwin, 1874; Miller,

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Chris Loersch, Department of Psychology and Neuroscience, University of Colorado; Nathan L. Arbuckle, Department of Social Sciences and Humanities, University of Ontario Institute of Technology, Oshawa, Ontario, Canada.

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Correspondence concerning this article should be addressed to Chris Loersch, Department of Psychology and Neuroscience, E328-B Muenzinger Hall, University of Colorado, Boulder, CO 80309-0345. E-mail: chris.loersch@colorado.edu

2000), a tool for creating social bonds (e.g., Dunbar, 2012; Freeman, 2000), a signal of group cohesiveness (e.g., Hagen & Bryant, 2003), a "social reward" system (e.g., Brown, 2000), and a device of social coordination (e.g., Roederer, 1984). Others have even argued that music did not evolve for any particular function and is a simple epiphenomenon (e.g., Patel, 2003; Pinker, 1997). Amazingly, despite the abundance of theories, thought pieces (e.g., www.purposeofmusic.com; www.pbs.org/wnet/musicinstinct), and books on the topic (e.g., Ball, 2010; Bannan, 2012; Mithen, 2007; Sacks, 2007; Wallin, Merker, & Brown, 2001), this long-standing debate has remained almost entirely philosophical. Very little empirical evidence exists for any perspective.[1]

In the current work we argue that music evolved as a form of social communication, a tool to pass information about the group's shared mental state to a number of individuals at once, without direct face-to-face interaction. Although demonstrating the veracity of such evolutionary arguments is a long-term challenge than cannot be accomplished by any single article, this basic perspective does suggest a number of testable hypotheses. After outlining our account, we provide seven studies that examine some of these core predictions. Through these studies, we demonstrate that people's responses to music are intricately tied to their social behavior in other, completely nonmusical domains. These results provide some of the first direct evidence regarding the purpose of music, demonstrating its inherently social nature and helping to establish human musicality as a unique form of social cognition.

On the Function of Music

The foundation of our work is the idea that human musicality, like so many other features of behavior and cognition (Caporael & Baron, 1997; Caporael & Brewer, 1995), evolved in service of group living.[2] This hypothesis centers on music's unique ability to influence the mood and behavior of many people at once, helping to mold individual beings into a coordinated group. The power of music to accomplish this feat is exemplified by its well-documented use in organizing military action (Tzu, 400 B.C./1994) and creating social bonds through ritualized drumming (S. G. Wilson, 1992). In both cases, music is crucial for organizing group action, instantly transmitting information about the group's proper pace of movement and emotion state (Juslin, 2003; Sievers, Polansky, Casey, & Wheatley, 2012; Steinbeis & Koelsch, 2011) across distance to many individuals at once.

Importantly, the use of music eliminates the need to pass social information throughout the group using direct one-on-one communication, a time-consuming process that frequently changes the original message (Allport & Postman, 1947; Schachter & Burdick, 1955) and is more susceptible to interpersonal negotiation processes (Cross & Woodruff, 2009; Grice, 1975; Schwarz, 1996) and counterarguing (Billig, 1996; Cross, 2011; Petty, Tormala, & Rucker, 2004). In addition, the information contained within music appears to affect behavior at a relatively automatic level without (necessarily) requiring a listener to possess culturally transmitted semantic structures. This is evidenced by the fact that 5-month old infants already display spontaneous physical entrainment to the music they hear (Zentner & Eerola, 2010), as well as cross-cultural research demonstrating that the emotion communicated by music is not dependent on shared cultural meaning (Fritz et al., 2009; Sievers et al., 2012). In sum, it appears that music automatically passes social information about the group's mood and behavior and does so in a more effective manner than many other routes of communication.

In essence, then, our proposal is that the trait of human musicality (i.e., responsivity to musical information in the environment) was selected for by the same evolutionary pressures that made humans favor group living. As it became increasingly adaptive for humans to live in social groups, various biological (de Groot, Smeets, Kaldewaij, Duijndam, & Semin, 2012; Stern & McClintock, 1998) and psychological (Caporael & Baron, 1997; Caporael & Brewer, 1995) mechanisms evolved in order to create and maintain a group structure. Because of the observation that music is able to simultaneously affect the mood and behavior of many individuals at once, we (and those who favor similar perspectives) hypothesize that human musicality is one of these mechanisms. If a human group consists of individuals who are all responsive to music, then this communicative tool can be used to perform a number of critical social functions.

Music can, for example, help move the group toward a common goal by communicating social information about the group's proper mental state (i.e., pace of movement and mood, see Juslin, 2003; Steinbeis & Koelsch, 2011). This can be observed in modern society when aggressive music is played during sporting events, helping to create the emotion and energy necessary to confront a rival group (e.g., see Virginia Tech playing *Enter Sandman* by Metallica at football games, *http://www.youtube.com/watch?v=blzftASduNcitalic>). Because music automatically elicits bodily movement in time with the beat (Zentner & Eerola, 2010), it can also be used to create movement synchrony among individuals. This entrainment process is of vital importance because simple movement synchrony has been shown to create social bonds (Hove & Risen, 2009; Lakin & Chartrand, 2003; Lakin, Jefferis, Cheng, & Chartrand, 2003; Oullier, de Guzman, Jantzen, Lagarde, & Kelso, 2008), increase cooperation between individuals (Wiltermuth & Heath, 2009), and increase perceived group entitativity (Lakens, 2010). Interestingly, there is recent evidence that movement synchrony in response to music is especially effective at facilitating the bonding process (Demos, Chaffin, Begosh, Daniels, & Marsh, 2011). This phenomenon can be easily observed in the coordinated actions of crowds at large music festivals (e.g., see Tomorrowland, http://www.youtube.com/watch?v=CZXFkgYb1ik#t=01m00italic>).[3] Together these functions help a group bond and coordinate its behavior, increasing the biological fitness of its members by creating a more effective social group.*

The Current Work

Although the evolutionary argument that we and others have made is impossible to fully examine in the context of a single article or set of studies, the perspective does generate a number of testable hypotheses. If this account is true, for example, then the

[1] For a relatively comprehensive review of the various theories, see Cross (2007) and the special issue of *Musicae Scientiae* on music and evolution (2009, Issue 13).

[2] For similar perspectives, see also Brown (2000); Huron (2001); Merker, Madison, and Eckerdal (2009); Roederer (1984); and Ujhelyi, (2000).

[3] If interested readers find that the example videos are unavailable at the listed URLs, please contact Chris Loersch.

tendency to be affected by musical information in the environment should be an innate feature of human cognition. Evidence for this hypothesis is provided by findings that music processing has its own specialized neural circuitry (Molnar-Szakacs & Overy, 2006; Peretz, 2006), that 5-month old infants spontaneously move in time with novel music (Zentner & Eerola, 2010), and that neonates immediately display hemispheric specialization in music processing (Perani et al., 2010). Although largely counter to the theory that music is an epiphenomenon (Patel, 2003; Pinker, 1997), these findings are, of course, consistent with many different evolutionary-based theories. The current work is designed to examine another basic hypothesis that is more exclusive to the present perspective: that musical reactivity is, at heart, a group process.

The basic prediction derived from this hypothesis is as follows: If music evolved to bind individuals into a group and facilitate group living, then musical reactivity should be related to the other psychological processes that serve a similar function. That is, when situations arise that cause people to pay special attention to social information, they should also become more attuned to the social content inherent in the music to which they're exposed. If this is the case, then we should be able to observe a direct relationship between people's musical reactivity and their social behavior and motivation in completely nonmusical situations. We examined this prediction in seven studies. Together, these studies utilize a mixture of individual difference and experimental approaches, multiple operationalizations of musical reactivity, and a variety of subject populations. Across paradigms, measures, and populations, we hypothesized that musical reactivity would be significantly related to other group processes that exist in service of social living, even when they control behavior in completely nonmusical domains.

Part 1: Individual Differences in Objective Musical Reactivity

The studies in this first section examine individual differences in people's emotional reactions to actual music. We hypothesized that measuring reactivity to music would allow us to obtain an indicator of each participants' current level of social motivation. If music is a core social process, then the degree to which it affects people should vary alongside their susceptibility to other group processes. Because these basic social motives fluctuate naturally across situations (Brewer, 1991; Leonardelli, Pickett, & Brewer, 2010; Turner, Oakes, Haslam, & McGarty, 1994), assessing musical reactivity should essentially provide us with a psychological marker of people's current motivation to behave as a group member, thereby allowing us to use it to predict their social behavior in other, nonmusical, situations.

Study 1

In order to provide an initial test of these hypotheses, we first developed a measurement procedure that could provide an objective assessment of the extent to which individuals are affected by the music they hear. After completing this musical reactivity assessment, participants were placed in a classic intergroup discrimination situation (Brewer, 1979; Tajfel, Billig, Bundy, & Flament, 1971). During this task, they were asked to allocate resources to two anonymous individuals, one of whom belonged to the same group (i.e., was an ingroup member), and one of whom did not. We selected this task because it measures the extent to which individuals are motivated to preferentially allocate resources to fellow ingroup members, a behavior that increases the group's resources and helps ensure that it will survive future hardships. If people's reactions to music are indeed driven by their current sensitivity to group processes, then we should be able to use musical reactivity scores to predict behavior in the resource allocation task.

Participants. Seventy-six students from the University of Missouri completed the study for partial course credit.

Materials and procedure.

Objective musical reactivity assessment. Upon entering the lab, participants first completed an objective measure of musical reactivity. In this procedure, individuals listened to music during two short surveillance tasks (approximately 2 min in length). In each, they were exposed to a rapidly changing stream of random letters, numbers, and nonwords of varying color, size, and duration. The target object (i.e., 105 or *lyt*; depending on surveillance task) was randomly presented five times throughout the task. Participants were asked to monitor the stimuli for this target, pressing the spacebar as quickly as possible when it appeared. Music played throughout and ended abruptly when the task was complete. The music was either a fast, happy song (*Soul Makossa* by Manu Dibango) or a slow, sad song (*Mercy Now* by Mary Gauthier). Each song was paired with a different surveillance task. Participants were informed they would be hearing music during the tasks but were given no other explanation for its presence.

As a measure of emotional responsivity to the music, participants rated the feelings they had just experienced during the surveillance task using the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). This scale was administered twice, immediately after each surveillance task was complete. It consists of 20 words that describe different feelings and emotions (e.g., *afraid, alert, excited, interested, irritable, upset*). Participants rated the extent to which each described the emotions they felt during the surveillance task using a 5-point scale anchored at 1 (*Very slightly or not at all*) and 5 (*Extremely*). The items were presented in a single, randomly determined order. To calculate musical reactivity, we subtracted participants' ratings for each item after the first surveillance task from their ratings for that same item after the second. We then took the absolute value of each of these 20 difference scores and averaged them to obtain our index of musical reactivity. Higher values represent greater reactivity to the music heard during the tasks.[4] To ensure that this measure was not confounded with general mood, song-order was counterbalanced such that one-half of participants were randomly assigned to listen to the fast, happy song first while the other half listened to the slow, sad song first. This counterbalancing factor did not qualify the results of this (or any other) study and will not be discussed further.

Resource allocation task. After the musical reactivity assessment, participants completed a series of six Tajfel matrices. Validated across decades of research on group processes (Bourhis, Sachdev, & Gagnon, 1994), participants' responses on this set of

[4] We also utilize an additional polynomial regression analysis (see Edwards, 1994, 2002; Laird & De Los Reyes, 2013) to demonstrate that our results are not driven by reactions to only one of the two songs.

standardized matrices (Tajfel et al., 1971) served as our measure of ingroup bias. Every matrix consists of 13 columns, with two rows of numbers in the columns. On each trial, participants select a single column that represents the number of points they want to allocate to two anonymous individuals. In our version of the task, the only information they had about these people was the school that they attended. This was manipulated so that one person was an ingroup member, attending the same university as our participants (i.e., the University of Missouri). The other individual was an outgroup member that attended the University of Toronto. We selected this outgroup target because American college students typically have little experience with individuals attending Canadian universities.

The critical aspect of these matrices is that the point totals participants choose from are highly constrained. By manipulating the point options, the matrices present a variety of behavioral strategies, including fairness (allocating equal points to both individuals), maximizing joint profit (giving the most points possible to both individuals), maximizing ingroup profit (giving the most points to the ingroup individual), and maximizing group differences (creating the greatest difference in point allocations between the ingroup and outgroup members). Although we measured the use of each strategy (see Table 1 for the full set of results), our primary dependent measure was simply the overall amount of ingroup bias exhibited during the task. To calculate this variable, we separately summed the number of points allocated to the ingroup and outgroup individuals across all six trials. We then subtracted the point total for the outgroup member from the point total for the ingroup member. This provided an index of the extent to which participants were motivated to preferentially provide resources to people from their own group (higher numbers represent greater degrees of ingroup bias).

Results. Replicating decades of past research, we found a substantial ingroup bias in the resource allocation task. Participants distributed significantly more points to the ingroup member than the outgroup member ($M = 21.46$, $SD = 28.08$), $t(75) = 6.66$, $p < .01$, $d = 0.76$. Unsurprisingly, people were also emotionally affected by the music they heard; musical reactivity scores were significantly greater than zero ($M = 0.65$, $SD = 0.43$), $t(75) = 13.30$, $p < .01$, $d = 1.51$. Critically, the predicted relationship between these two variables was significant ($r = .31$, $p < .01$; see Figure 1).[5] Thus, measuring the impact of the social content communicated by music allowed us to predict the extent to which participants were currently motivated to support their ingroup during the resource dilemma task. Readers well-acquainted with the Tajfel matrices can view Table 1 for a breakdown of all social motivations measured by the matrices and their simple bivariate relationships with musical reactivity.

Table 1
Resource Allocation Biases and Strategy Orientations (i.e., Pull Scores) in Study 1

Strategy orientation	*M*	*SD*	MR correlation
Overall ingroup bias	21.46	28.08	.31*
Ingroup total	97.00	14.72	.23*
Outgroup total	75.54	16.34	−.33*
FAV on MJP	5.37	4.95	.27*
MJP on FAV	0.63	2.93	.04
FAV on P	1.74	5.86	.26*
P on FAV	6.29	5.87	−.25*
MD on (MIP + MJP)	1.26	4.66	.02
(MIP + MJP) on MD	3.59	4.40	.20

Note. Means (and standard deviations) for resource allocation biases and strategy orientations (i.e., pull scores) in Study 1, including each measure's correlation with musical reactivity. MR = Musical Reactivity; FAV = ingroup favoritism; MJP = maximum joint profit; MD = maximum difference in favor of ingroup; MIP = maximum ingroup profit; P = parity.
* $p < .05$.

Because difference scores are by definition highly correlated with their constituent components, it is possible that this effect could be driven by participants' reactions to only one of the songs to which they were exposed. To address this concern, we also analyzed our data using a polynomial regression technique recommended by change score specialists (see Edwards, 1994, 2002; Laird & De Los Reyes, 2013). This allowed us validate our reactivity measure by ensuring that it was change in mood that accounted for our effects. To conduct this analysis, we first computed variables representing participants' moods after the fast/happy song and slow/sad song. This was done by creating single composite mood scores from the 20 positive and negative PANAS items. These variables were coded such that higher scores represent more positive mood. As outlined by Laird and De Los Reyes (2013), we then entered these two mood scores, two terms representing each of these variables squared, and the interaction between the two mood scores into a multiple regression with resource allocation bias as the outcome of interest. The critical test of whether mood change truly drives the effect is whether the interaction is significant with these other terms in the model. Confirming our primary analysis, the interaction between mood after the positive song and mood after the negative song was a significant predictor of ingroup bias ($\beta = -.39$), $t(70) = 2.64$, $p = .01$, $r^2 = .08$. This demonstrates that the results were indeed produced by change in mood rather than emotional reactions to only one of our two musical pieces.

Discussion. Although the musical reactivity assessment and resource allocation task are completely unrelated measurement tools, participants' responses on the two were significantly related. From our perspective, the reason this relationship emerged is because both measures assess core social processes that developed to facilitate group living. This supports our general theory regarding the development of human musicality and helps establish music as a group process. Although the results provide initial evidence for our perspective, some questions remain. One issue,

[5] As can be seen in Figure 1, the structure of the Tajfel matrices naturally produced a strong bimodal distribution, with one mode containing individuals utilizing a strategy biased toward parity ($N = 52$) and the other containing individuals who strongly favored the ingroup over the outgroup ($N = 24$). Unfortunately, this pattern of data caused the residuals resulting from our primary analysis to violate the assumption of homogeneity of error variance. To address this concern, we ran a logistic regression in which participants were coded as falling into these two modes (based on Figure 1 we selected a resource allocation bias of 30 as the cut point). This analysis replicated our earlier findings; musical reactivity was a significant predictor of participant group ($b = 1.72$), Wald $\chi^2(1, N = 76) = 7.34$, $p = .01$. As musical reactivity increased, so did the likelihood that participants were located in the strong ingroup bias mode.

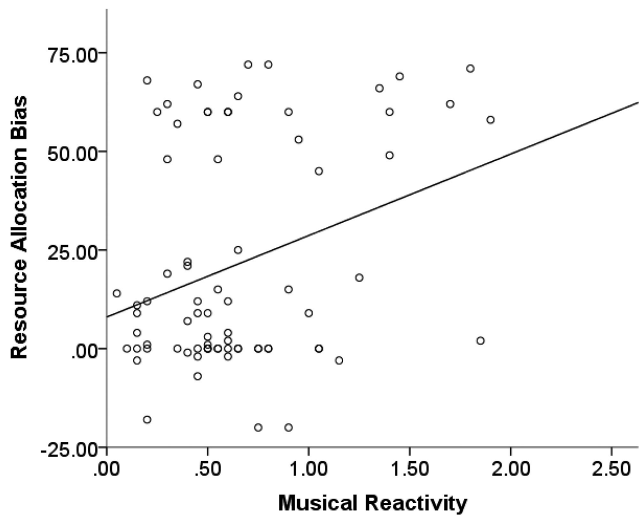

Figure 1. Scatter plot of participants' resource allocation bias and musical reactivity scores in Study 1.

for example, is the possibility that our musical reactivity measure assesses general emotional reactivity. Thus, Study 1 may be demonstrating that people who are more emotionally affected by *any* environmental stimuli also display stronger group biases. Although this would be an interesting finding of its own right, it would obviously alter the implications of our findings. To rule out this possibility, Study 2 sought to provide a conceptual replication of the results, while separately measuring participants' emotional reactions to music and other nonmusical stimuli.

Study 2

Study 2 utilized two between-subject conditions to separately assess musical reactivity and general emotional reactivity. To expand on the results of Study 1, we also included a new dependent measure, an ingroup–outgroup implicit association test (IAT) that allowed us to assess the relative positivity of participants' evaluative associations toward their ingroup (see also Pinter & Greenwald, 2011). We found this task attractive because it measures a basic cognitive bias in the way people categorize ingroup-related stimuli and assesses this construct without asking individuals to consciously reflect on the topic. The use of this measure helps eliminate the concern that our prior results may be driven by demand effects and allows us to demonstrate that our findings can generalize to a more reflexive form of behavior than that assessed in Study 1. In addition, the relative valence of people's evaluative associations has been shown to be situationally variable (Blair, 2002), modulating in a goal-relevant manner in order to facilitate appropriate approach or avoidance behavior (Ferguson & Bargh, 2004). Because of these features, this dependent measure allowed us to examine a nondeliberative form of ingroup favoritism that should vary as people become more or less focused on behaving as a group member and has been related to many other core group processes (Greenwald, Poehlman, Uhlmann, & Banaji, 2009). Paralleling our predictions from Study 1, we expected that knowing a person's musical reactivity score would allow us to predict the extent of evaluative bias in their cognitive associations with the ingroup. Critically, if our findings are truly about participants' reactions to music, then general emotional reactivity scores should not show this same pattern of results.

Participants. One-hundred and sixteen students from the University of Colorado participated for partial course credit. These individuals were randomly assigned to one of two conditions in a single factor (reactivity assessment stimulus type: music vs. pictures) between-subjects design.

Materials and procedure.

Reactivity assessment. Upon arrival to the experiment, participants completed the same basic surveillance task procedure described in Study 1. To obtain an objective measure of emotional reactivity to nonmusical stimuli, participants in the picture condition viewed valenced images instead of listening to music. Picture valence differed across the two surveillance tasks. Mimicking the music condition, order was counterbalanced such that one-half of participants were randomly assigned to first view positive pictures (e.g., a baby, a puppy, a kissing couple) while the other half first viewed negative pictures (e.g., a car wreck, cockroaches on food, people fighting). Ten positive and 10 negative pictures were selected from the International Affective Picture Set (Lang, Bradley, & Cuthbert, 1995). Each was randomly presented for 6 s during the surveillance task. This extended the length of each surveillance task by 1 min. The procedure was virtually identical to that described in Study 1 for participants in the music condition. The only change was that an image of a black square containing a single fixation cross was randomly presented 10 times for 6 s during each surveillance task. This served to equate task length in the music and picture conditions. Music played throughout the task. All other aspects of the procedure remained the same.

Ingroup–outgroup implicit association test. After assessing reactivity scores, participants completed an ingroup–outgroup IAT (adapted from Pinter & Greenwald, 2011). As in the common IAT procedure (Greenwald, McGhee, & Schwartz, 1998), on each trial of the ingroup–outgroup IAT participants are presented with one of four stimulus types (positive words, negative words, ingroup-related stimuli, outgroup-related stimuli) and two category labels. Their task is to categorize each stimulus as quickly as possible using one of two response keys. On "simple" trials, participants are presented with stimuli related to just two categories (e.g., pleasant vs. unpleasant). On the critical task trials, however, participants are presented with stimuli from all four categories. Each of the two response keys is then used to identify two separate stimulus types. As demonstrated repeatedly within the large literature surrounding the IAT (e.g., see Greenwald et al., 2009), the degree of association between the categories determines the ease with which individuals can corepresent them using a single response key. Thus, by varying the categories that share a response, an IAT can be used to measure the extent to which two concepts are currently associated.

Using the ingroup–outgroup IAT, we measured the extent to which participants currently associated their ingroup (the University of Colorado) and an outgroup (the University of Toronto) with the evaluative categories pleasant and unpleasant. We chose to target evaluative associations because their valence has been shown to be highly variable across situations (Blair, 2002), with the relative positivity of particular associations being automatically modulated in order to facilitate appropriate approach or avoidance behavior (Ferguson & Bargh, 2004). Thus, if participants are currently motivated to behave as a group member, they should evaluate ingroup-related stimuli in a relatively positive manner.

To measure these evaluative associations, we included standard positive and negative stimuli (e.g., *honor, happy, sunrise*; *filth, tragedy, sickness*) and paired them with both ingroup-related stimuli (i.e., *CU, Colorado, Buffaloes, we, ours*) and outgroup-related stimuli (i.e., *Toronto, Canada, Maple-leafs, them, they*). The category labels used throughout the task were *Pleasant*, *Unpleasant*, *University of Colorado*, and *University of Toronto*. During two "compatible" critical blocks, participants saw stimuli from all four categories and were required to categorize each as either related to the University of Colorado or Pleasant (using one key) or related to the University of Toronto or Unpleasant (using the other). The two "incompatible" critical blocks used the reverse categorization pairings (i.e., "*University of Colorado or Unpleasant"* vs. "*University of Toronto or Pleasant"*). Our IAT consisted of seven blocks with 40 trials in each of these four critical blocks and 20 trials in each of three simple blocks (220 total trials). Label side and the order of the critical blocks were counterbalanced between participants. These factors did not qualify the reported results (all *F*s < 1) and will not be discussed further.

Our outcome of interest was ingroup bias in participants' evaluative associations, measured by assessing the relative ease with which participants associated the ingroup with positivity (and the outgroup with negativity). This was done by subtracting the mean accuracy rate in the "incompatible" blocks ("*University of Colorado or Unpleasant*" vs. "*University of Toronto or Pleasant"*) from the mean accuracy rate in the "compatible" blocks ("*University of Colorado or Pleasant"* vs. "*University of Toronto or Unpleasant*"). As recommended by Greenwald et al. (1998), responses on the first two trials of each block were excluded from these analyses. Higher scores indicate relatively more positive associations with the ingroup.[6]

Results. As in Study 1, we found a general ingroup bias. Participants' accuracy was significantly higher in the "compatible" blocks ($M = 0.93$, $SD = 0.07$) than the "incompatible" blocks ($M = 0.91$, $SD = 0.08$), $t(115) = 1.96$, $p = .05$, $d = 0.27$. Thus, we obtained evidence that the ingroup was generally associated with more positivity than the outgroup. As can be seen from the distribution of reactivity scores displayed in Figure 2, participants were emotionally affected by the stimuli presented during the two surveillance tasks ($M = 0.67$, $SD = 0.42$), $t(115) = 17.31$, $p < .01$, $d = 1.60$. Individuals in the picture viewing condition did, however, experience more mood change ($M = 0.78$, $SD = 0.47$) than participants in the music condition ($M = 0.55$, $SD = 0.32$), $t(114) = 3.10$, $p < .01$, $d = 0.59$. Importantly, the amount of ingroup bias expressed on the IAT was not affected by the type of stimuli participants were exposed to during the reactivity assessment, $t < 1$.

As in Study 1, our primary analysis concerned the relation between these two measures. To test our hypothesis that musical reactivity would be related to the current positivity of ingroup attitudes but general emotional reactivity would not, we conducted a regression analysis in which participants' IAT accuracy bias was predicted by their reactivity score, the type of stimuli they were exposed to during the reactivity assessment (i.e., music vs. pictures), and the interaction between these two factors. As hypothesized, this interaction was significant ($\beta = -.96$), $t(112) = 2.73$, $p = .01$, $r^2 = .06$ (see Figure 2). Replicating Study 1, musical reactivity significantly predicted the amount of ingroup bias demonstrated on the IAT ($\beta = .63$), $t(112) = 3.75$, $p < .01$. General emotional reactivity, however, did not ($\beta = .08$), $t < 1$, $p = .47$.[7]

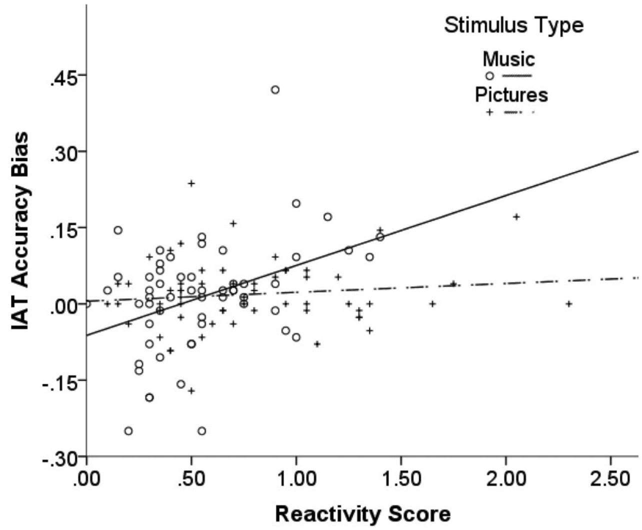

Figure 2. Scatter plot of participants' IAT accuracy bias and reactivity scores in Study 2, with separate prediction lines for participants in the music and picture conditions. IAT = implicit association test.

As in Study 1, we sought to verify that the effects were driven by change in mood. Another polynomial regression analysis was conducted as described in Study 1, however a third factor representing stimulus type (picture vs. music) was also entered into the regression model (along with its interactions with all other variables). As expected, the three-way interaction between mood after the positive stimulus, mood after the negative stimulus, and stimulus type was significant ($\beta = -.84$), $t(104) = 2.26$, $p = .03$, $r^2 = .04$. This was driven by the fact that the key two-way interaction between the two mood scores found in Study 1 held for participants in the music condition ($\beta = -1.57$), $t(104) = 2.45$, $p = .02$, $r^2 = .05$, but not for those in the picture condition ($\beta = -.05$), $t < 1$, $p = .78$. Again, this verifies that our effects were driven by change in mood rather than participants' responses to only one of our two songs.

Discussion. These findings are important in a number of regards. First, we replicate Study 1 in that musical reactivity was related to another basic form of social bias in a completely nonmusical domain. Musical reactivity scores predicted the relative ease with which participants categorized ingroup-related stimuli as positive. In addition to replicating Study 1, this result also dem-

[6] Although past research has examined IAT effects using both accuracy and reaction times, we focused on accuracy because the *d*-score measure of reaction time bias did not show significant ingroup bias ($t < 1$). As outlined in the subsequent footnote, however, both measures showed the same pattern of results.

[7] Although the critical interaction was not significant ($\beta = -.42$), $t(112) = 1.14$, $p = .26$, $r^2 = .01$, examination of reaction time data from the IAT (i.e., a d-score bias measure with a 600 ms error penalty; see Greenwald, Nosek, & Banaji, 2003) showed the same basic pattern of results. The *d*-score measures' correlation with ingroup bias was marginally significant for participants in the musical reactivity condition ($\beta = .32$), $t(112) = 1.83$, $p = .07$, but nonsignificant for participants in the emotional reactivity condition ($\beta = .08$), $t < 1$, $p = .49$.

onstrates that the effects generalize to other forms of ingroup bias. In this case, we examined a relatively nondeliberative bias in the basic evaluative content participants associated with their ingroup. As before, we propose that this relationship emerged because the ingroup–outgroup IAT and musical reactivity assessment both measure cognitive processes that developed in order to facilitate group living. Finally, these results further validate our perspective by demonstrating that this relationship was present when our reactivity measure assessed responses to music but not when it measured general emotional reactivity. This suggests that the findings of both Study 1 and Study 2 provide unique information about the meaning of people's reactions to music.

Part 2: Individual Differences in Subjective Musical Reactivity

Although the research reported in the previous section provides initial evidence for our hypotheses, there are some important limitations that are inherent in the design of the objective musical reactivity assessment used in that section's studies. Because this measure requires participants to listen to particular songs, it is possible that the relationships we observed are driven by people's reactions to these individual pieces rather than music in general. Although our polynomial regression analyses help alleviate the concern that the results were caused by only one of the two songs we used, the findings remain open to this basic criticism. Because *any* music that we might select would be subject to the same concerns, we chose to utilize a completely different measure of musical reactivity in the Individual Differences in Subjective Musical Reactivity section. Here, we instead utilize a questionnaire measure of musical reactivity that asks participants to reflect on their subjective reactions to music during their daily lives. This allowed us to examine general reactivity to music, rather than reactions to the particular pieces we selected.

Study 3

The primary purpose of this study was to provide convergent validity for our previous results by assessing musical reactivity using a new methodology and relating this measure to another important social construct. Instead of assessing objective reactions to music, we measured subjective musical reactivity by asking participants to directly rate the extent to which they are affected by music during their daily life. We then examined whether musical reactivity was associated with the need to belong (Leary & Kelly, 2009). We chose this variable because it is a core social motive that binds us into groups (Baumeister & Leary, 1995). Furthermore, it has been related to a general sensitivity to social information (Pickett, Gardner, & Knowles, 2004), the same underlying process we argue produces musical reactivity. In addition, we included a questionnaire measure of emotional reactivity to further demonstrate that our results are due to musical reactivity rather than general reactivity to emotionally evocative stimuli. Finally, the study sought to examine whether we could obtain this relationship in a broader, noncollegiate population. This was accomplished by posting the study on Amazon's Mechanical Turk site. Study signup was restricted to U.S. participants.

Participants. Two hundred and twelve individuals residing in the United States participated for monetary compensation through Amazon's Mechanical Turk system (Buhrmester, Kwang, & Gosling, 2011). Eight of these individuals did not complete all three of our dependent measures and were dropped from the sample, leaving 204 participants in the final analyses. In addition to the psychological questionnaires, demographic questions were asked about participants' age (M = 30.44, SD = 9.05, Min = 18, Max = 65), ethnicity (78.0% Caucasian, 8.4% African American, 7.9% Asian American, 2.5% Hispanic, 2.5% other/no response), and gender (122 men, 80 women). Two participants did not answer the demographic questions.

Materials and procedure.

Need to belong questionnaire. After the consent process, we assessed participants' current level of belonging motivation (Baumeister & Leary, 1995). This was measured using the 10-item need to belong scale constructed by Leary and colleagues (Leary, Kelly, Cottrell, & Schreindorfer, 2012). It assesses individual differences in the desire for interpersonal attachments (Leary & Kelly, 2009) and has been related to increased sensitivity to social information (Pickett et al., 2004). For each item, participants indicate the extent to which they agree or disagree using a 5-point scale ranging from 1 (*Strongly disagree*) to 5 (*Strongly agree*). Sample items include: "*If other people don't seem to accept me, I don't let it bother me*" (reverse scored), and "*I try hard not to do things that will make other people avoid or reject me.*" Appendix Table A3 lists all 10 questions. Responses to these 10 items were averaged to create an index of the need to belong (α = .87).

Subjective musical reactivity. After completing the need to belong questionnaire, participants were asked to report on their musical reactivity. In order to obtain a subjective measure of musical reactivity, we created a 15-item questionnaire that assessed participants' personal impressions of their responses to music. For each item, participants were asked to rate the extent to which a provided statement described their reactions to music on a 7-point scale ranging from 1 (*Not at all*) and 7 (*Completely*). Sample items include "*When I hear a fast song, I feel like becoming more active,*" "*When I listen to music, I can feel it in my body,*" "*When I listen to music, I can feel it affect my mood,*" and "*When I hear music, my foot starts tapping along with the beat.*" See Appendix Table A1 for a list of all 15 items (α = .90).

Subjective emotional reactivity. Finally, participants completed the affect intensity measure (Larsen, 1984, 2009; Larsen & Diener, 1987) to assess their general emotional reactivity. This questionnaire (Larsen, 1984) asks participants to report on the subjective intensity of their emotional reactions to various situations. The scale lists statements such as "*I get upset easily*," "*I am a fairly quiet person*" (reverse scored), and "*I get really happy or really unhappy*" and asks participants to rate how often each statement is descriptive of their emotional reactions on a 6-point scale ranging from 1 (*Never*) to 6 (*Always*). Because we were interested in general emotional reactivity, we did not administer three of the 20 items that directly targeted social emotions (i.e., pity, empathy, and shame/guilt; "*When a person in a wheelchair can't get through a door, I have strong feelings of pity*," "*Seeing a picture of some violent car accident in a newspaper makes me feel sick to my stomach*," and "*I would be very upset if I got a traffic ticket.*"). The full set of 17 items is also detailed in Table A1 (α = .79).

Results. Our primary hypothesis was simple, that levels of musical reactivity (M = 4.89, SD = 1.00) would allow us to predict participants' current need to belong (M = 3.06, SD =

0.72). As expected, these two constructs were significantly correlated ($r = .18$, $p = .01$; see Table 2 for the bivariate correlations among all measures). Having provided evidence for our primary prediction, our second goal was to examine whether musical reactivity could be empirically distinguished from general emotional reactivity. We approached this question through the use of an exploratory factor analysis, examining whether the individual items from the musical and emotional reactivity scales formed distinct factors. To conduct this analysis, we Z-scored the 32 individual items that composed our musical reactivity and emotional reactivity measures (reverse coded items were first rescored) and then examined their factor structure using principle axis factoring and promax rotation. Visual inspection of the scree plot showed two primary factors, the only factors with eigenvalues higher than three. Together, these two factors accounted for 36% of the variance in participants' responses. Appendix Table A1 shows the individual item loadings from the pattern matrix. These values represent the unique, nonshared variance each question contributes to the extracted factors. From examination of these loadings, it was clear that the two factors represented (a) musical reactivity (eigenvalue = 7.46; 23.3% of the variance explained), and (b) general emotional reactivity (eigenvalue = 4.04; 12.6% of the variance explained). Unsurprisingly, these two factors were significantly correlated ($r = .20$, $p < .01$). Thus, although the presence of these two distinct factors establishes musical reactivity as a unique construct that extends beyond general emotional reactivity, it is also clear that the forms of reactivity are related.

We next examined whether these two distinct factors also provided unique predictive ability. To do this, we conducted a multiple regression analysis in which the musical and emotional reactivity factors were both used to predict the need to belong. This allowed us to examine whether each factor uniquely predicted social motivations controlling for levels of the other. Here again, we found evidence for the distinctiveness of the musical reactivity construct. Both the musical reactivity ($\beta = .14$), $t(201) = 2.11$, $p = .04$, and the emotional reactivity factors ($\beta = .31$), $t(201) = 4.65$, $p < .01$, were unique predictors of the need to belong.[8] Although they both relate to this social outcome, they account for distinct portions of variance.

Discussion. In sum, these results replicate and extend the basic findings reported in the previous section. Musical reactivity was once again related to a core social motivation. Critically, this occurred when measuring people's subjective impressions of their general musical reactivity rather than their reactions to particular songs. Presumably, each of our participants actively imagined very different music while completing this measure, thereby providing evidence that the results of our earlier studies generalize to musical reactivity more broadly. Replicating Study 2, we also found that musical and emotional reactivity were empirically distinct constructs. This was evident both from the presence of two unique factors in the factor analysis and from the fact that the musical reactivity and emotional reactivity factors provided unique predictive ability. Although both related to participants' current level of belonging motivation, they accounted for unique, nonoverlapping variance in this construct. Thus, it appears that the two constructs relate to the need to belong for very different reasons. Finally, because we utilized a noncollegiate sample, these results also provide some evidence that the basic relationship between musical reactivity and social motivation generalizes to a broader population.

Table 2
Correlations Among Variables in Study 3

Measure	1	2	3	4	5
1. Musical Reactivity	—				
2. Affect Intensity	.19*	—			
3. Need to Belong	.18*	.40*	—		
4. Musical Reactivity factor	.98*	.24*	.20*	—	
5. Emotional Reactivity factor	.13†	.93*	.34*	.20*	—

† $p < .10$. * $p < .05$.

Study 4

In Study 4, we sought to replicate the findings of Study 3 while providing additional evidence for the conceptual and empirical uniqueness of the musical reactivity construct. Having established that musical reactivity is distinct from general emotional reactivity, we examined an even more basic form of reactivity in this study. To accomplish this, we used Aron and Aron's (1997) measure of sensory-processing sensitivity (SPS). This construct has been proposed to reflect a general biological reactivity and has been identified as a genetically determined trait that involves greater sensitivity to subtle stimuli and relates to higher levels of emotional reactivity (Aron, Aron, & Jagiellowicz, 2012). In addition, it has been argued that sensory processing sensitivity in part underlies our evolution as social animals. Aron et al. (2012) state that being high in SPS "is assumed to have particular benefits for social animals, including humans, by being able to gratify others by making their needs more accessible, conform to others when that is adaptive, or sense untrustworthiness in others" (pp. 276–277). Because of these features, replacing the emotional reactivity measure used in Study 3 with this construct allows us to provide a particularly strong test of the relative uniqueness of musical reactivity. Finally, to extend our prior findings, Study 4 also increased the number of social outcomes examined. In addition to the need to belong (Leary & Kelly, 2009), we also included a self-esteem questionnaire (Rosenberg, 1965), an in-house measure of ingroup (university) identification, and a behavioral measure of ingroup bias (i.e., the Tajfel resource allocation task, see Study 1).

Participants. One hundred and sixty students at the University of Colorado participated in the study for partial course credit.

Materials and procedure. Upon being brought into the laboratory, participants completed six tasks. As in the Study 3, task order was held constant for all participants, with the measures administered in the order described below. Musical reactivity was assessed last to ensure that any relationships found were free of contamination from the particular musical content considered by participants as they completed this measure. Although sample items are provided for all new questionnaires, a full list of all items administered can be viewed in Appendix Tables A2 and A3.

[8] We also conducted this multiple regression analysis using raw scores computed from the two scales. This produced the same basic pattern of results. Musical reactivity was a marginal, positive predictor ($\beta = .10$, $p = .11$), and the affect intensity measure was a significant positive predictor ($\beta = .38$, $p < .01$.

Resource allocation task. Resource allocation bias was measured using the same procedure described in Study 1. The anonymous individuals to whom points were allocated were from the University of Colorado and the University of Toronto. Our outcome measure was the single item index representing the total amount of ingroup bias (i.e., points allocated to the ingroup–points allocated to the outgroup).

Need to belong questionnaire. Need to belong was measured with the same 10-item scale used in Study 3 (α = .76).

Self-esteem. Self-esteem was measured using the 10-item Rosenberg Self-Esteem Scale (α = .90; Rosenberg, 1965). Sample items are "*On the whole, I am satisfied with myself*," "*I am able to do things as well as most other people*," and "*At times, I think I am no good at all*" (reverse coded). Participants rate the extent to which they agree with each statement on a 4-point scale ranging from 1 (*Strongly Agree*) to 4 (*Strongly Disagree*). This construct was selected because past research has found that self-esteem is related to a sense of social worth (Leary, Tambor, Terdal, & Downs, 1995; Tafarodi & Swann, 1995).

Biological reactivity. In order to assess general biological reactivity, we administered Aron and Aron's (1997) measure of sensory-processing sensitivity. This consists of a 27-item battery assessing participants' sensitivity to various external events (α = .85). Sample items are "*To what extent do you seem to be aware of subtleties in your environment?*" "*To what extent do you startle easily?*" and "*To what extent are you easily overwhelmed by things like bright lights, strong smells, coarse fabrics, or sirens close by?*" Participants answer each question on a 7-point scale ranging from 1 (*Not at all*) to 7 (*Extremely*).

Ingroup identification. Participants' identification with the University of Colorado was assessed using a 9-item in-house measure. Sample items are "*To what extent do you feel pride when learning of the accomplishments of other University of Colorado students?*" "*How important is being a University of Colorado Buffalo to you?*" and "*How often do you wear clothing associated with the University of Colorado (e.g., CU sweaters, caps, shirts, etc.)?*" Each item was answered using a 7-point scale ranging from 1 (*Not at all*; *Never*) to 7 (*A lot*; *All the time*). Although unpublished, this scale has consistently achieved high reliabilities in our lab, an outcome replicated in this sample (α = .84).

Subjective musical reactivity. Finally, subjective musical reactivity was measured with the same 15-item scale used in Study 3 (α = .91).

Results. As in Study 3, we first examined whether knowing a participants' level of musical reactivity would allow us to predict their responses to the various social outcome measures. Table 3 provides the full correlation matrix for all administered measures.

Table 3
Correlations Among Dependent Measures in Study 4

Measure	1	2	3	4	5	6
1. Musical Reactivity	—					
2. Sensory Processing Sensitivity	.41*	—				
3. Need to Belong	.24*	.32*	—			
4. Rosenberg Self-Esteem	−.05	−.25*	−.19*	—		
5. Ingroup Identification	.15*	−.04	.13†	.21*	—	
6. Resource Allocation Bias	−.08	−.01	.09	.03	.24*	—

† $p < .10$. * $p \leq .05$.

Replicating our prior results, musical reactivity ($M = 4.95$, $SD = 1.09$) was again a significant predictor of the need to belong ($M = 3.32$, $SD = 0.66$). Those individuals who were most reactive to music also had a higher need to belong ($r = .24$, $p < .01$). This same pattern was also obtained for our measure of ingroup identification ($M = 3.85$, $SD = 1.10$). Participants with higher levels of musical reactivity identified more strongly with their university ingroup ($r = .15$, $p = .05$). Counter to our predictions, subjective musical reactivity was not related to either self-esteem ($M = 3.12$, $SD = 0.58$) or ingroup biases in resource allocations ($M = 16.60$, $SD = 25.47$, both rs $< .08$, ps $> .32$). Despite these nonsignificant relationships, however, our initial analyses both replicate and extend the results of Study 3. Musical reactivity was a significant predictor of both belonging motivation and ingroup identification. Having established these basic findings, we next turned our attention to examining whether musical reactivity could be empirically distinguished from general biological reactivity. To accomplish this, we utilized the same factor analytical technique described in Study 3.

Predictor variable factor analysis. The 42 individual items that composed our musical reactivity and sensory-processing sensitivity measures were first Z-scored and then submitted to an exploratory factor analysis (utilizing principle axis factoring and promax rotation). The scree plot displayed evidence of a two-factor solution. These were the only two factors with eigenvalues greater than three and together accounted for 31% of the variance in participants' responses. In examining the individual item loadings from the factor pattern matrix (see Appendix Table A2), it was clear that these two factors represented (a) musical reactivity (eigenvalue = 9.13, 21.7% of the variance explained) and (b) general biological reactivity (eigenvalue = 4.06, 9.7% of the variance explained). The presence of these two distinct factors helps establish musical reactivity as a unique construct that extends beyond general reactivity to environmental stimuli.

Outcome variable factor analysis. Because we suspected that many of the questions administered as outcome variables would tap similar constructs, we also conducted a second factor analysis. Our goal was to use the factors extracted from this analysis as more pure indicators of the various social constructs we had measured. For this, we Z-scored the 30 items that composed these measures and then factor analyzed them using the same analysis technique described above. All items requiring reverse coding we recoded before they were Z-scored. For our behavioral measure, we simply Z-scored the single item index representing ingroup bias in point allocations.

Perhaps unsurprisingly, examination of the scree plot from this analysis provided evidence of three primary factors. These were the only factors with eigenvalues higher than two and together accounted for 45% of the variance. Examination of the individual item loadings from the pattern matrix (see Appendix Table A3) made it clear that these three factors represented (a) self-esteem (eigenvalue = 6.30, 21.0% of the variance explained), (b) ingroup identification (eigenvalue = 4.41, 14.7% of the variance explained), and (c) belonging motivation (eigenvalue = 2.88, 9.6% of the variance explained).

Relationships among predictor and outcome variables. Having extracted the variance unique to the musical reactivity and biological reactivity constructs, we next examined how these latent variables related to our social outcome factors. The basic bivariate correlations are displayed in Table 4. As can be seen from these results, there is considerable conceptual overlap between musical

Table 4
Correlations Among Factor Scores in Study 4

Measure	1	2	3	4	5
Predictor factors					
1. Musical Reactivity	—				
2. Biological Reactivity	.44*	—			
Outcome factors					
3. Self-Esteem	−.04	−.35*	—		
4. Ingroup Identification	.14†	.03	.23*	—	
5. Belonging Motivation	.25*	.34*	−.23*	.15*	—

† $p < .10$. * $p \leq .05$.

and biological reactivity. Unsurprisingly, those individuals who react strongly to music have strong reactions to nonmusical stimuli as well ($r = .44$, $p < .01$). Critically, the factor representing the unique variance of musical reactivity continued to be related to participants' levels of belonging motivation ($r = .25$, $p < .01$), further demonstrating that our results are not simply due to the musical reactivity measure tapping general reactivity to environmental stimuli. Finally, conceptually replicating the results of Study 3 with emotional reactivity, there was also a significant relationship between general biological reactivity and the need to belong ($r = .34$, $p < .01$).

We next examined whether the musical reactivity and biological reactivity factors accounted for unique variance in our three outcome factors. By including both the musical and biological reactivity factors as simultaneous predictors in a multiple regression analysis we were able to see whether one factor predicted each social outcome controlling for levels of the other. For self-esteem, only musical reactivity showed the expected positive relationship. Musical reactivity was a marginally positive predictor of this factor ($\beta = .14$), $t(157) = 1.66$, $p = .10$, while general biological reactivity was a significant negative predictor ($\beta = -.41$), $t(157) = 4.94$, $p < .01$. The two forms of reactivity were also differentially related to ingroup identification. Here musical reactivity was a marginal positive predictor ($\beta = .16$), $t(157) = 1.83$, $p = .07$, but biological reactivity was not ($\beta = -.04$), $t < 1$, $p = .63$. Finally, both reactivity factors were positively related to belonging motivation, although musical reactivity was a less strong predictor ($\beta = .13$), $t(157) = 1.52$, $p = .13$, than biological reactivity ($\beta = .28$), $t(157) = 3.40$, $p < .01$. Table 5 lists the partial beta weights resulting from each of these multiple regression analyses for both the factor scores and the raw summary scores that were calculated from the administered scales.

Because we initially hypothesized that musical reactivity would have a significant positive relationship with all of the social outcomes, we ran one final analysis to examine this prediction. In this analysis, we sought to create a single item index of "social tendencies." We did this by Z-scoring and then averaging our three social outcome factors. As expected, the musical reactivity factor was positively related to this aggregate ($r = .19$, $p = .02$). We then examined whether musical and biological reactivity differentially related to this summary variable by including both factors in a multiple regression analysis. Musical reactivity was a significant predictor ($\beta = .23$), $t(157) = 2.68$, $p = .01$, but biological reactivity was not ($\beta = -.09$), $t(157) = 1.06$, $p = .29$. This pattern of results was mirrored when we instead used raw scale scores as predictors. Here, the musical reactivity scale was a significant predictor ($\beta = .21$), $t(157) = 2.50$, $p = .01$, but sensory processing sensitivity was not ($\beta = -.06$), $t < 1$, $p = .48$.

Discussion. Together, these results conceptually replicate and extend a number of our prior findings. Most importantly, we directly replicated the findings of Study 3. As before, knowing participants' subjective musical reactivity scores allowed us to predict their level of belonging motivation. Study 4 also extended these results by showing that musical reactivity could be used to predict the extent to which participants identified with a salient ingroup, other students at the University of Colorado. In addition, the predictor variable factor analysis demonstrated that musical reactivity was empirically separable from general biological reactivity. As was found with emotional reactivity in Study 3, this analysis produced evidence of two distinct, but related, factors. Although our multiple regression analyses were ambiguous in some regards, in sum they provided evidence for the conceptual distinctiveness of musical and biological reactivity. Only musical reactivity showed the expected positive relationships with all three social outcome factors. Biological reactivity, on the other hand, was only a positive predictor of belonging motivation. It was negatively related to self-esteem and unrelated to levels of ingroup identification. Finally, only musical reactivity was significantly related to an aggregate "social tendencies" variable. Together with Study 3, these results help demonstrate that musical reactivity is, indeed, a novel construct that is uniquely related to social outcomes as predicted by our perspective on the evolutionary function of music.

Study 5

As the concluding study in this section, Study 5 was conducted to address three final concerns. First, because the two prior studies both utilized a fixed order of presentation, it is possible that the relationship between musical reactivity and the need to belong emerged because of some artifact of the experimental procedure. To address this issue, Study 5 administered all measures in a randomly determined order and explicitly tested whether order moderated the findings. Second, in Studies 3 and 4, we only measured constructs that were expected to show some positive relationship with musical reactivity and then relied on a factor

Table 5
Correlations and Partial Beta Weights for Factor Scores and Scales in Study 4

Measure	1a	2a	1b	2b
Predictor factors correlations				
1a. Musical Reactivity	—			
2a. Biological Reactivity	.44*	—		
Predictor scales correlations				
1b. Musical Reactivity	.99*	.40*	—	
2b. Sensory Processing Sensitivity	.48*	.94*	.41*	—
Outcome factors partial beta weights				
3. Self-Esteem	.14†	−.41*	.07	−.29*
4. Ingroup Identification	.16†	−.04	.20*	−.08
5. Social Sensitivity	.13	.28*	.12	.26*
Outcome scales partial beta weights				
6. Rosenberg Self-Esteem	.13	−.38*	.06	−.27*
7. Ingroup Identification	.16†	−.08	.21*	−.13
8. Need to Belong	.12	.32*	.13	.27*

† $p < .10$. * $p < .05$.

analytical approach to demonstrate that our construct was empirically distinct from these other reactivity measures. In this study we replaced these variables with a nonsocial construct that should not be related to musical reactivity, thereby providing additional discriminant validity. This allows us to demonstrate that musical reactivity is not simply a positive predictor of any other construct that might be measured. To accomplish this, we selected the need for cognition scale (Cacioppo & Petty, 1982; Cacioppo, Petty, & Kao, 1984), a self-report questionnaire assessing people's need for and enjoyment of effortful thought. We chose this construct because the scale has been very widely used, having been included in over 200 published articles. In addition, it has been related to a diverse set of phenomena (for review see Cacioppo, Petty, Feinstein, & Jarvis, 1996; Petty, Briñol, Loersch, & McCaslin, 2009) including lucid dreaming (Patrick & Durndell, 2004), persuasion (Briñol & Petty, 2005), stereotyping (Carter, Hall, Carney, & Rosip, 2006), and creativity (Blagrove & Hartnell, 2000). Critically, although it has been related to a host of other scales and mental processes, the need for cognition does not assess a social motive and should not be positively related to musical reactivity. Finally, we sought to demonstrate that the link between self-reported musical reactivity and need to belong would emerge in an even broader sample than that used in our previous research. To accomplish this, we administered the study on Amazon's Mechanical Turk but relaxed the national enrollment restrictions so that we could obtain an international sample.

Participants. One hundred and twenty-three individuals participated for monetary compensation through Amazon's Mechanical Turk system. Participation was not restricted by country, allowing individuals from any country in the world to complete the survey (provided that they could read English and were 18 or older). In addition to the psychological questionnaires, demographic questions were asked about participants' age (M = 30.39, SD = 8.83, Min = 18, Max = 58), ethnicity (63.4% Asian,[9] 17.9% Caucasian, 15.4% other, 3.3% no response), country of origin (72.4% India, 8.1% United States, 3.3% United Kingdom, 16.2% other), and gender (49 women, 72 men, 2 no response).

Materials and procedure. The following three questionnaires were administered in a random order, determined separately for each participant.

Subjective musical reactivity. Musical reactivity was measured with the same scale used in Studies 3 and 4 (α = .90).

Need to belong questionnaire. Need to belong was measured with the same scale used in Studies 3 and 4 (α = .71).

Need for cognition questionnaire. To provide a measure of discriminant validity, participants also completed the need for cognition scale. This was done using an 18-item scale that assesses individual differences in the willingness to engage in and liking of mental elaboration (Cacioppo et al., 1984). For each item, participants indicate the extent to which a statement is characteristic of their self using a 5-point scale ranging from 1 (*Extremely uncharacteristic of me*) to 5 (*Extremely characteristic of me*). Sample items include "*Thinking is not my idea of fun*" (reverse scored), and "*I usually end up deliberating about issues even when they do not affect me personally.*" These 18 items were averaged, with higher numbers representing a stronger need for cognition (α = .84).

Results. Replicating the results of the other studies in this section, musical reactivity (M = 3.26, SD = 0.95) was significantly related to the need to belong (M = 3.30, SD = 0.56, r = .34, p < .01). Contrary to our expectations, there was a marginal negative relationship between musical reactivity and need for cognition (M = 3.31, SD = 0.60, r = −.15, p = .09). Surprisingly, there was also a negative association between the need to belong and need for cognition (r = −.32, p < .01). Paralleling our analyses in Studies 3 and 4, we next examined whether musical reactivity and the need for cognition accounted for unique variance in the need to belong. When both variables were simultaneously entered into a multiple regression analysis, musical reactivity was a significant positive predictor (β = .30), t(120) = 3.60, p < .01, and need for cognition was a significant negative predictor (β = −.27), t(120) = 3.28, p < .01. Finally, to examine the impact of questionnaire order on our core predictions, we coded whether musical reactivity was assessed before or after the need to belong. Mean levels of the need to belong and musical reactivity did not differ depending on order (both ts < 1). Order of assessment also did not moderate the relationship between musical reactivity and the need to belong. A regression model in which the need to belong was predicted from musical reactivity, order (contrast coded), and the interaction of the two yielded only a significant effect for musical reactivity (β = .34), t(119) = 4.00, p < .01. Neither order (β = −.03, t < 1, p = .93), nor its interaction with musical reactivity were significant (β = −.06, t < 1, p = .84). Furthermore, the relationship between the two constructs was significant both when musical reactivity was measured before the need to belong (β = .33), t(119) = 2.50, p = .01, and when measured after (β = .36), t(119) = 3.16, p < .01.

Discussion. Together, the results from the second part of our research repeatedly demonstrate the basic link between musical reactivity and group processes. Despite measuring musical reactivity with a completely different assessment procedure, we replicated the basic findings obtained in the previous section. In all three studies, the extent to which participants felt that they were affected by music allowed us to predict their level of general belongingness motivation, one of the core human motives that helps bring us together into social groups (Leary & Kelly, 2009). Furthermore, although individuals high in musical reactivity were reactive to nonmusical stimuli, musical reactivity was empirically distinct from both emotional and biological reactivity. Study 5 also provided discriminant validity by showing that musical reactivity was not positively related to the need for cognition. Critically, the basic relationship between musical reactivity and social belonging motivation were replicated in all three studies, including in a university-based lab experiment (Study 4), a broader, nationwide sample (Study 3), and an international sample consisting of 92% foreign participants (Study 5). These studies also introduced a new subjective measure of musical reactivity that has high reliability ($\alpha \geq .90$ in all samples) and is easy to administer. Finally, Study 5 showed that these results hold regardless of assessment order, making it unlikely that the observed relationships were due to any particular questionnaire's influence on participants' responses to the other scales.

[9] This includes participants who entered "Indian" into the free response ethnicity question.

Part 3: Manipulating Musical Reactivity

Together, the first and second parts of our research establish the basic connections between musical reactivity and a number of other group processes that have been well-documented for their importance in producing social behavior. In addition to providing repeated evidence for our basic prediction regarding the social nature of music, the work demonstrates that these relationships are robust across different measures of musical reactivity and a variety of subject populations. Finally, many of the studies in these sections also showed that musical reactivity could be empirically separated from other forms of reactivity. Together, these studies demonstrate that our results do indeed speak to the function of people's reactions to music. In our third and final section, we now turn from the individual difference approach and instead utilize experimental designs that allow us to provide causal evidence for the core link between musical reactivity and group processes.

By using this experimental approach, the studies in this final section are designed to provide the most direct evidence for our overarching hypotheses and, in doing so, to address a number of remaining concerns. The first is a conceptual issue of vital importance. That is, one conclusion that might be drawn from the findings documented to this point is that only certain people are responsive to music and it is these individuals who also display social biases in other tasks and situations. Although generally consistent with the results of previous sections, we do not feel that this is the proper way to conceptualize these findings. As with social motivations and behaviors more broadly, we believe that being responsive to music is a core psychological process that characterizes the basic human condition. Although there are trait level differences, the degree to which people express all of these social behaviors also vary substantially across time and situations. This has been shown for many other group processes, which affect behavior at varying levels as people differentially focus on meeting their social versus individual needs (Brewer, 1991; Leonardelli et al., 2010; Turner et al., 1994). We suspect that the individual differences approach used in the two previous sections largely succeeded by capitalizing on these natural variations in people's social focus, with situational variability in this construct producing a substantial portion of the relationships we observed.

In this third part of our research, we sought to demonstrate that this hypothesis is true; that musical reactivity, like other group processes, would naturally increase when people become focused on behaving as a group member by the current situation. To accomplish this, we took advantage of a well-documented fact of social life: Because humans are inherently motivated to be valued members of their social groups (Baumeister & Leary, 1995; Leary & Kelly, 2009), anything that threatens the need to belong causes people to pay special attention to social information and engage in behaviors aimed at reaffirming their status in the group (Williams, 2007). If the critical function of music is to communicate social information about the group's common mental state, then musical reactivity should be affected by this type of social threat. That is, individuals who become motivated to reestablish their value to the group should become more affected by music. Critically, if this effect emerges, it also assuages one final concern about the results from earlier sections of the article. That is, because the first and second sections both rely on a correlational approach, there are an infinite number of alternative explanations for the findings. Through the use of experimental designs, the studies in the current section can lay such concerns to rest, providing direct causal evidence for the proposed link between group processes and musical reactivity.

Study 6

In Study 6 we threatened (or affirmed) participants' sense of belonging in an important group. We then measured musical reactivity using the objective assessment procedure described in Study 1. We predicted that those participants who were threatened would become more sensitive to the social information communicated by music, displaying a significant increase in their level of musical reactivity.

Participants. Ninety-eight students from the University of Missouri participated for partial course credit. These individuals were randomly assigned to the conditions of a single factor (social belonging: threat vs. affirmation) between-subjects design. Five participants were eliminated from the sample because they did not view the University of Missouri as part of their self (for additional details see the self–group overlap section below), leaving 93 participants in the final analyses.

Materials and procedure.

Social belonging manipulation. Upon entering the lab, participants were exposed to our social belonging manipulation. It was embedded in a five-item questionnaire that asked participants about their recent behavior as a student at the university. The questions, each answered using a 5-point scale, were (a) "*Roughly how many articles of clothing do you possess which have an MU logo or design?*" (b) "*In the last year, how many university sponsored events did you attend (e.g., sports matches, recitals, lectures, plays, etc.)?*" (c) "*Over the academic year, how many times did you miss class?*" (d) "*In the last year, how often did you say positive things about the University of Missouri to other potential students?*" and (e) "*In the last year, how many times did you participate in the M-I-Z, Z-O-U chant?*"

We used a biased questionnaire methodology (Dillehay & Jernigan, 1970) to threaten or affirm social belonging, altering each question's response options depending upon condition. In the threat condition, the response options caused participants to select a relatively low scale point. For example, the five response options available for the first question about the amount of university sponsored clothing owned ranged from 1 (*10 or less*) to 5 (*30 or more*). In contrast, participants in the affirmation condition were given response labels ranging from 1 (*Zero*) to 5 (*4 or more*). Each question followed this basic pattern, causing participants in the threat condition to select a very low response option, while participants in the affirmation condition were led to choose higher response options.

The critical aspect of this manipulation is the normative information communicated by these response options (Dillehay & Jernigan, 1970; Grice, 1975). Because participants naturally assume that the questions provide viable response options, those individuals in the threat condition are left with the impression that they are poor group members compared to their peers (i.e., don't possess as many clothes with the university logo on them, go to as many sporting events, participate in as many cheers, etc.). Alternatively, by selecting the higher response options, participants in the affirmation condition are left with the impression that they are relatively good group members.

Objective musical reactivity assessment. After completing the social belonging manipulation, participants' objective musical reactivity was measured using the same assessment procedure described in Study 1.

Self–group overlap. Because one can only threaten or affirm the social identity of participants who include the targeted group in their self-concept, we also included a pictorial measure of self–group overlap (Schubert & Otten, 2001). Administered after the reactivity assessment, this item presented participants with six images that represented varying amounts of overlap between their self and the University of Missouri. Each image contained two circles of different colors, with one representing the self and the other representing the group. These were arranged to create a linear scale, ranging from 1 (*no overlap, two circles separated by space*) to 6 (*complete overlap, two merged circles*). Participants were asked to select the one option that represented the amount of overlap between their self and the University of Missouri. Responses to this question were unaffected by the social-belonging manipulation ($t < 1$).

Results and discussion. A manipulation check confirmed that participants in the threat condition used significantly lower scale points when answering the social belonging questions ($M = 2.10$, $SD = 0.78$) than participants in the affirmation condition ($M = 4.58$, $SD = 0.59$), $t(91) = 17.30$, $p < .01$, $d = 3.63$. More importantly, the manipulation also produced the predicted effect. Individuals in the threat condition had higher musical reactivity scores ($M = 0.72$, $SD = 0.50$) than those in the affirmation condition ($M = 0.52$, $SD = 0.30$), $t(91) = 2.29$, $p = .02$, $d = 0.48$.[10] In addition, the manipulation had no effect on general mood (as measured after either surveillance task, both ts < 1), suggesting that it selectively affected participants' social motivation. This provides direct causal evidence for the link between group processes and music. Those participants who felt as though they were poor group members became more affected by the music they heard.

Study 7

Our final study was a conceptual replication and extension of Study 6. Primarily, we sought to demonstrate that the causal relationship documented there would emerge a second time, even when using a different manipulation of social threat. We also addressed a number of additional areas of concern. The first regards the direction of the effect documented in Study 6. Because we contrasted threat and affirmation conditions, it is unclear which produced the observed effect. Study 7 ameliorated this issue by comparing social threat to a neutral control condition. In addition, we sought to provide further evidence for the distinction between musical and emotional reactivity by demonstrating that social threat would increase responsiveness to music, but not to other emotionally evocative, but nonmusical, content. We also improved on the methodology used to separate these two factors in Study 2. There, we examined reactivity to either music or emotional pictures. Although only musical reactivity was significantly related to our social outcome measure, these two conditions differed on an important dimension that introduced a potential confound. That is, one condition measured reactivity to auditory information while the other measured reactivity to visual content. Because the channel of information processing varied across conditions, it is possible that this fact drove the differential correlations observed. In the current study, we altered our procedure to enable both music and general emotional content to be presented aurally.

Finally, we altered our objective musical reactivity measure in two important ways. The first was to change the music participants listened to. Because Studies 1, 2, and 6 included songs featuring singing, we felt it was important to include a study with purely instrumental music to demonstrate that our effects are due to music per se, rather than the vocal content embedded within musical information. In addition, we only exposed participants to a single song of either positive or negative valence and then calculated musical reactivity using change in mood from a pretest baseline. This allowed us to provide a stronger demonstration that our effects held over both types of songs and were not driven by reactions to one particular valence of music.

Participants. One hundred and thirty-eight individuals residing in the United States participated for monetary compensation through Amazon's Mechanical Turk. These individuals were randomly assigned to the conditions of a 2 (social belonging: threat vs. control) × 2 (stimulus type: music vs. words) × 2 (stimulus valence: positive vs. negative) between-subjects design. Twelve individuals were excluded for satisficing and providing straight-line responses on our dependent measure (Krosnick, 1991), this resulted in a final sample of 126 participants. We also collected the following demographic data: age ($M = 34.72$, $SD = 12.88$, $Min = 18$, $Max = 65$), ethnicity (70.6% Caucasian, 7.9% Black or African American, 6.3% Asian or Asian American, 5.6% Hispanic, 1.7% other/no response), and gender (71 women, 44 men, 1 no response). Ten participants did not provide responses for these demographic questions.

Materials and procedure.

Reactivity assessment. Upon beginning the experiment, all participants completed an initial baseline mood assessment. As in our prior studies, we used the PANAS for this purpose. Participants were simply asked to answer questions about "their current mood" before beginning the experiment. After the social belonging manipulation (described below), participants completed a "visual memory task" that required them to view a short 3 min 15 s video. Participants were informed that we would ask them various questions about the video's content and were interested in the ways in which auditory information altered these memory processes. This video contained only neutral content and consisted of in-game footage from the video game *Minecraft* in which youtube.com member "theinternetftw" showcases a 16-bit computer that was built using only in-game physical objects.

To manipulate the auditory information to which participants were exposed, we removed this video's soundtrack and embedded our own content. In the music conditions, participants listened to one of two instrumental songs, either the fast, happy track, *Tighten Up* by The Bamboos, or the slow, anxious song, *World Police and*

[10] We also ran this analysis with the full sample, including those participants with no self–group overlap. As might be expected, the size of this effect was slightly reduced but remained significant (via one-tailed test); individuals in the threat condition had higher musical reactivity scores ($M = 0.69$, $SD = 0.50$) than those in the affirmation condition ($M = 0.54$, $SD = 0.31$), $t(96) = 1.76$, $p = .08$, $d = 0.36$.

Friendly Fire by Godspeed You! Black Emperor. In the words condition, participants instead listened to an audio recording in which either 18 positive (e.g., toy, flower, bunny, rainbow, etc.) or negative (e.g., rat, flood, bees, fungus, etc.) nouns were read aloud, one approximately every 10 s. The words were selected and matched for relative valence using the Affective Norms for English Words database (Bradley & Lang, 1999). After viewing this video, participants completed the PANAS a second time, indicating the extent to which they felt each emotion "while watching the video." We computed musical reactivity scores from these two PANAS ratings using the same procedure described in Study 1. After this task, participants answered four questions about their memory for the content of the video, responded to the demographic questions listed above, and then completed a funnel-debriefing procedure which probed for recognition of the music played during the experiment.

Social belonging manipulation. Between the initial PANAS and the visual memory task, participants completed a "cyberball" game (Williams & Jarvis, 2006). This was selected because of its well-documented use as a manipulation of social belonging motivation (Williams, Cheung, & Choi, 2000). In this task, participants log onto a web-server and play a simple ball tossing game with two computerized partners. Belonging is manipulated by controlling the percentage of throws that the participant receives from the other two group members. In our threat condition, participants were ostracized from the group. Here, they received the ball on one of the first few throws and were then excluded for the remainder of the game (30 total throws). In the neutral, control condition, participants continued to receive the ball from their partners, getting it thrown to them approximately one-third of the time. Past research has documented that this is a powerful manipulation of social belonging (Eisenberger, Jarcho, Lieberman, & Naliboff, 2006) that motivates people to effortfully reestablish their social value (Williams, 2007; Williams et al., 2000). Furthermore, it has been established that the nonostracism version of the cyberball game we used effectively functions as a neutral control condition (Wesselmann, Bagg, & Williams, 2009; Wesselmann, Wirth, Mroczek, & Williams, 2012).

Results. To examine our hypotheses, reactivity scores were submitted to a 2 (social belonging manipulation: threat vs. control) × 2 (stimulus type: music vs. word) × 2 (stimulus valence: positive vs. negative) analysis of variance. Our primary prediction was that the threat manipulation would cause an increase in reactivity to music, but not reactivity to nonmusical stimuli. Furthermore, this basic two-way interaction should not be moderated by the valence of the stimulus to which participants were exposed. That is, threatened participants should become more sensitive to the social information transmitted by either positive or negative music.

These predictions were confirmed; there was a significant interaction between social belonging condition and the reactivity assessment stimulus type (see Figure 3), $F(1, 118) = 4.14$, $p = .04$, $\eta_p^2 = .03$. Critically, this effect was not qualified by the three-way interaction of these factors and stimulus valence, $F(1, 118) = 1.29$, $p = .26$, $\eta_p^2 = .01$. Simple effects analyses showed that the predicted two-way interaction was driven almost exclusively by the increase in reactivity for participants who listened to music after being ostracized. These individuals were significantly more reactive ($M = .64$, $SD = .58$) than participants who also listened to music but had not been ostracized ($M = .49$, $SD = .35$), $F(1, 118) = 4.54$, $p = .04$, $\eta_p^2 = .04$. They were also more reactive than the other ostracized participants who instead listened to valenced words, $F(1, 118) = 3.66$, $p = .06$, $\eta_p^2 = .03$. Among those individuals who listened to the nonmusical content, there was no difference in reactivity scores between the threat condition ($M = .49$, $SD = .35$)[11] and the neutral, control condition ($M = .53$, $SD = .41$, $F < 1$). Finally, it is important to emphasize that within the neutral condition, reactivity scores did not differ as a function of stimulus type ($F < 1$). For these nonthreatened individuals, both types of stimuli were equally emotionally evocative.[12]

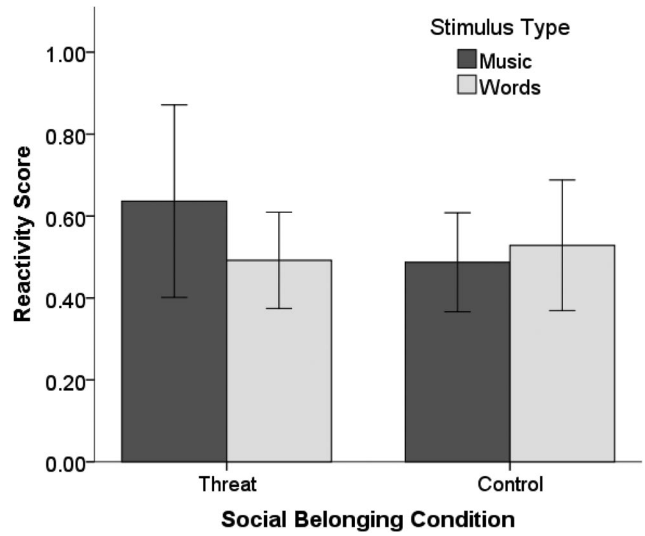

Figure 3. Mean reactivity in Study 7 as a function of social belonging condition and reactivity assessment stimulus type. Error bars represent the 95% confidence interval.

Discussion. Together, this pattern of results drives home a number of critical points for our investigation. First, we again observed the basic causal relationship between social belonging threat and musical reactivity. As in Study 6, those individuals who were threatened became more sensitive to the social content transmitted by the music they heard. Importantly, the design of the current experiment allowed us to demonstrate that this effect was driven by the threat condition and was not dependent on the actual valence of the music heard. This helps establish that our findings are truly about musical reactivity and are not simply due to a

[11] The means and standard deviations of participants in the threat/word condition and control/music condition round to identical values.

[12] In the funnel-debriefing at the conclusion of our experiment, we asked participants whether they had recognized the musical selections. If participants answered "yes," we asked them to freely recall either the song or artist. Thirteen individuals (out of 61) claimed to have recognized the music, four of whom were able to name either the band or song they had heard. As a conservative test of whether our results were driven by listening to familiar music, we reran our primary analysis excluding all 13 participants who indicated any recognition memory. The critical interaction between the social belonging manipulation and stimulus type remained marginally significant, $F(1, 95) = 2.71$, $p = .10$, $\eta_p^2 = .03$, and continued to be unqualified by stimulus type ($F < 1$). This reduction in significance level seemed to be driven primarily by the loss of power, as the basic pattern of means did not change.

motivational drive to achieve a particular type of mood after social belonging threat. By including conditions in which participants instead listened to either positive or negatively valenced words, we were also able to demonstrate that this causal effect is specific to musical reactivity and does not occur for reactivity to emotionally evocative, but nonmusical, stimuli. The fact that reactivity scores did not differ as a function of stimulus type within the neutral condition also bolsters our conclusions by showing that the results are not simply driven by baseline differences in the emotional effects of listening to valenced words instead of music. Finally, although the results from the second section already provided substantial evidence that our effects generalize beyond reactions to particular songs, the current findings provide further support for this conclusion. That is, the results of our earlier studies replicate even though we altered the songs used in our objective musical reactivity assessment to fully instrumental pieces.

General Discussion

Music is unique in its ability to transmit social information across distance to a number of people at once. Because of this, it allows a group to communicate without speech or direct interaction and, with the proper tools, enables this to happen across a much greater space than these other routes would allow. These facts suggest that human musicality evolved in service of group living. Although such arguments have been philosophically compelling to many, empirical evidence on the topic is sorely lacking. Instead, scientific research on music has been largely limited to an examination of *how* our mind processes musical information (e.g., Koelsch, 2011; Koelsch & Siebel, 2005; Molnar-Szakacs & Overy, 2006; Perani et al., 2010; Peretz, 2006), rather than trying to understand *why* it does so. Importantly, while there are many indirect findings that are consistent with the current perspective on the evolutionary function of music, our research is among the first to directly test the hypotheses that derive from this account.

In sum, across seven studies, we demonstrated that musical reactivity (i.e., the extent to which an individual is affected by the music they hear) is directly tied to a variety of other well-established group processes that underlie social living. In Study 1, we used musical reactivity as a psychological marker of sensitivity to social information and then used it to identify the degree to which people would display ingroup bias in a situation of intergroup discrimination. As musical reactivity scores increased, so too did the extent to which participants were motivated to alter their behavior on the basis of group membership. In Study 2, we provided evidence for the validity of our musical reactivity measure and demonstrated that the relationship documented in Study 1 was also present when examining ingroup bias on an implicit, nondeliberative measure. Musical reactivity was significantly related to the current ease of associating ingroup-related stimuli with positivity. Studies 3, 4, and 5 documented the same basic relationship: Musical reactivity allowed us to predict the current level of social belonging motivation endorsed by participants. In addition, these studies provided evidence that our findings do not rely on reactivity to a particular song. Perhaps the most important data for our claims were provided by Studies 6 and 7, where we demonstrated that musical reactivity is causally related to these basic social motivations. When participants' sense of belonging was threatened and they became motivated to reestablish social ties, they became more affected by the music they heard. This establishes a direct causal relationship between musical reactivity and social motivations and demonstrates that the relationships observed in the first and second sections of our research need not be limited to a certain type of individual. Critically, Studies 2, 3, 4, and 7 all demonstrated that musical reactivity is both conceptually and empirically separable from general reactivity to nonmusical stimuli. Finally, the generalizability of our findings was established through the use of widely varying samples that included undergraduates from two separate U.S. universities, more diverse U.S. based Mechanical Turk workers, and an international sample featuring 92% foreign participants.

In the present research, we have focused on reactivity to music and its relation to markers of successful group living. However, the broader perspective that we are testing is not limited to this link and suggests additional testable studies. For instance, if music evolved as a tool to communicate appropriate group affect, then it may be the case that music increases the efficacy of group performance on tasks that require cooperation or that groups of people chronically high in musical reactivity can outperform those chronically low in musical reactivity on collective tasks. We look forward to data on such possibilities and feel that the current work represents a crucial first step toward the examination of these related, "second-level" questions. It is hoped that the current data encourages other scientists to go beyond conjecture and begin collecting actual data on other evolutionary-based hypotheses. Only through such concerted empirical efforts will we make true progress on the function of human musicality.

Other Research on the Evolved Function of Music

To our knowledge, only two other articles have directly furnished data on the evolutionary function of music in humans. In the first, Hagen and Bryant (2003) had undergraduate students listen to music that varied in its degree of synchronization and rate the "coalition quality" of the musicians who made it (including items such as "*How willing do you think these men are to help each other?*" and "*How likely is it that these men will be friends 5 years from now?*"). The authors found that poorly synchronized music was perceived to be of lower quality and was associated with lower judgments of "coalition quality." The broader theory advanced by the authors suggests that music serves a social function, although a somewhat different one than we put forward. Specifically, they argue that the production of music serves as a reliable cue of coalitional quality, signaling to potential allies that the group is one worthy of cooperating with or to potential invaders that the group is a formidable opponent (Hagen & Bryant, 2003; Hagen & Hammerstein, 2009). This perspective is not necessarily opposed to our own in that it states that music production within a group is a *reliable* signal of coalition quality, implying that groups that make music function more effectively than those that do not. Our accounts differ in that we focus on music as an intragroup tool (i.e., helping coordinate behavior and enforce social ties within a social group), whereas they focus on the intergroup ramifications of music production (i.e., what effect does a group's music production have on the perceptions of nongroup members). We look forward to future research examining the extent to which these two perspectives relate human musicality to common or divergent social processes.

The only other research we were able to identify on this topic was recently published by Dunbar, Kaskitis, MacDonald, and Barra (2012). In this work, the authors measured the extent of endorphin release (operationalized through pain tolerance and positive affect) in participants after they had either engaged in music making or passively listened to music. This work was designed to test the authors' theory that music evolved in order to facilitate social bonding. Because endorphins are one chemical mediator of the bonding process, it was hypothesized that people who participated in music making (through clapping, drumming, or dancing) would display evidence of heightened endorphin release. The results bore out this prediction. Those individuals who actively participated in music had substantially higher pain tolerance and levels of positive affect than people who passively listened to music. Although the results of this work are somewhat limited by the fact that the authors used natural groups and did not randomly assign participants to conditions (e.g., in one study, 12 people practicing samba drumming were compared to nine individuals who had listened to ambient music while working at a musical instrument store), it does provide some interesting data on the social power of music. The extent to which it speaks to the underlying reasons why humans are emotionally affected by the music they hear is, however, unclear. Regardless, as is highlighted by our introduction, we are sympathetic to the authors' primary contention that music serves to enhance social bonding. Because a more closely bonded group should operate more effectively and display higher levels of social coordination (Stel et al., 2010), these results are, in many ways, consistent with our own perspective.

Finally, although not conducted to address the evolutionary purpose of music, there is other research that merges nicely with the current findings. Perhaps most compelling are clinical investigations of Williams syndrome. This is a relatively rare genetic disorder that causes people to be excessively social (Mervis & Klein-Tasman, 2000), such that these individuals are described as "hypersociable," and behave as if everyone in the world is their friend (Jones et al., 2000). This is also reflected in empirical data on the syndrome, with these individuals rating novel faces as more approachable than control participants (Jones et al., 2000). For our purposes, the most intriguing aspect of Williams syndrome is that these individuals are also more emotionally affected by music than controls (Don, Schellenberg, & Rourke, 1999). So, as in our work, we again see a tight relationship between musical reactivity and basic social motivations.

Limitations

Although we feel the present studies provide strong evidence in favor of our perspective, there are limitations. First, claims about human nature require a great diversity of data. We did go beyond the typical college undergraduates in Studies 3, 5, and 7, but the U.S. samples were predominately White, and the worldwide sample was predominately Indian. Future work in this area will need more diverse samples in order to provide evidence for the claims made about human nature (e.g., see Sievers et al., 2012). Additionally, there remain questions about how social traits like musicality evolved into a core feature of our species. Although some have argued that the evolution of these traits (cf. altruism) can only be explained using multilevel selection as a theoretical framework (e.g., see D. S. Wilson & Sober, 1994; D. S. Wilson & Wilson, 2007), others feel strongly that kin selection models offer a more accurate understanding of the evolutionary process (e.g., West, Griffin, & Gardner, 2007, 2008). For our purposes, knowing the precise evolutionary model by which social traits are selected is less important than understanding why they were selected in the first place. Joining others who share our theoretical perspective, we have argued that music evolved because of its inherent value within a group context. Although there remains much work to be done to fully explore the empirical ramifications of this perspective, the current data provide substantial evidence that human musicality should be considered alongside other social traits like altruism in these debates.

Conclusions

During his career, Charles Darwin articulated many of the core scientific ideas that have formed the basis for our current understanding of the world in which we live. Although his basic theory of evolution has spawned an immense amount of research over the years, a number of related questions have not been subjected to such empirical scrutiny. As highlighted by the quote in our introduction, one facet of life that mystified Darwin was the propensity for humans to make and enjoy music, a fact which led him to label musicality one of the "most mysterious" traits of humankind (Darwin, 1874). Despite the truly staggering amount of time and energy human cultures spend on music (cf. Sagan, 1978) and the continued philosophical interest in this basic question (e.g., Bannan, 2012), virtually no one has worked to empirically unravel the mystery of why we are a musical species. The current work represents our initial attempt to gain traction on this compelling and important problem.

Although the results of our studies certainly do not "prove" that music evolved to facilitate group living, they do demonstrate the generative ability of this perspective. Having developed our theory after many late nights of considering the power of both music and social motivations, we utilized this perspective to generate a number of novel predictions. Although we are not the first to make such arguments (e.g., see Brown, 2000; Huron, 2001; Merker, Madison, & Eckerdal, 2009; Roederer, 1984; Ujhelyi, 2000), to our knowledge we are among the first to design studies that could test these ideas and the first to provide a rigorous program of research on our perspective. The current work demonstrates the veracity of these hypotheses, providing some of the first true data on the relation between music and group processes. Although they don't unequivocally establish music's evolutionary purpose, they are difficult to account for from alternative perspectives. Together, these findings provide evidence that music is a group process, a special form of social cognition that may have evolved to serve the intense social needs of our species. This helps provide one answer for the basic mystery of why music evokes emotions (Juslin & Västfjäll, 2008) and suggests that the powerful psychological pull of music in modern life may derive from its innate ability to connect us to others.

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(*Appendix follows*)

Appendix

Factor Loading Tables

Table A1
Individual Question Loadings From Study 3 Factor Analysis

Questionnaire item	Factor 1: Musical Reactivity	Factor 2: Emotional Reactivity
Musical Reactivity		
MR1: When I hear a fast song, I feel like becoming more active.	**.44**	.21
MR2: When I choose music, I select it based on how it will make me feel.	**.54**	.09
MR3: When I listen to music, I can feel it in my body.	**.69**	−.01
MR4: When I listen to music, I can feel it affect my mood.	**.68**	−.03
MR5: I feel a strong emotional attachment to my favorite songs.	**.65**	−.04
MR6: When I hear a sad song, my mood begins to darken.	**.46**	.00
MR7: If music wasn't a part of my life, I would be a completely different person.	**.73**	−.16
MR8: When I hear a slow song, I start to slow down my actions.	**.57**	.00
MR9: When I hear a happy song, my mood begins to brighten.	**.62**	.16
MR10: My life would lose meaning if I couldn't listen to music.	**.69**	−.17
MR11: When I listen closely to music, I start to lose track of my immediate surroundings.	**.66**	−.09
MR12: When I listen to music my head moves along with the beat.	**.61**	.05
MR13: When I hear music, my foot starts tapping along with the beat.	**.61**	.04
MR14: If the right song comes on, I have trouble following another person's conversation.	**.65**	−.15
MR15: If I close my eyes and listen to music, the rest of the world starts to fade away.	**.72**	−.19
Affect Intensity Measure (Larsen, 1984)		
AIM1: When I feel happiness, it is a quiet type of contentment. (R)	−.34	.27
AIM2: I get upset easily.	.11	.11
AIM3: When I succeed at something, my reaction is calm contentment. (R)	−.20	**.46**
AIM4: I get really happy or really unhappy.	.23	.17
AIM5: I am a fairly quiet person. (R)	−.17	**.55**
AIM6: When I am happy, I feel very energetic.	**.41**	.40
AIM7: When I'm happy, I feel like I'm bursting with joy.	.31	**.56**
AIM8: When something bad happens, others tend to be more unhappy than I. (R)	−.17	.25
AIM9: Looking at beautiful scenery really doesn't affect me much. (R)	−.02	.36
AIM10: The weather doesn't affect my mood. (R)	.13	.19
AIM11: Others tend to get more excited than I do. (R)	−.09	**.79**
AIM12: I am not an extremely enthusiastic individual. (R)	−.06	**.69**
AIM13: "Calm and cool" could easily describe me. (R)	−.11	**.54**
AIM14: When I'm feeling well it's easy for me to go from being in a good mood to being really joyful.	.29	**.46**
AIM15: When I worry, it is so mild that I hardly notice it. (R)	−.09	.15
AIM16: I get overly enthusiastic.	.16	**.58**
AIM17: My happy moods are so strong that I feel like I'm "in heaven."	.23	**.41**

Note. Reverse coded items are indicated with an (R). These items were recoded before being entered into the factor analysis. Loadings greater than .4 are in bold. MR = Musical Reactivity; SPS = Sensory-Processing Sensitivity. The Affect Intensity Measure is from "Theory and Measurement of Affect Intensity as an Individual Difference Characteristic," by R. J. Larsen, 1984, *Dissertation Abstracts International: Section B. Sciences and Engineering, 85,* p. 2297. Copyright 1984 by R. J. Larsen.

(*Appendix continues*)

Table A2
Individual Question Loadings From Predictor Variable Factor Analysis in Study 4

Questionnaire item	Factor 1: Musical Reactivity	Factor 2: Biological Reactivity
Musical Reactivity		
MR1: When I hear a fast song, I feel like becoming more active.	**.66**	−.05
MR2: When I choose music, I select it based on how it will make me feel.	**.55**	.11
MR3: When I listen to music, I can feel it in my body.	**.80**	−.20
MR4: When I listen to music, I can feel it affect my mood.	**.72**	.01
MR5: I feel a strong emotional attachment to my favorite songs.	**.67**	−.10
MR6: When I hear a sad song, my mood begins to darken.	**.50**	.21
MR7: If music wasn't a part of my life, I would be a completely different person.	**.70**	−.17
MR8: When I hear a slow song, I start to slow down my actions.	**.54**	.12
MR9: When I hear a happy song, my mood begins to brighten.	**.63**	.00
MR10: My life would lose meaning if I couldn't listen to music.	**.62**	.01
MR11: When I listen closely to music, I start to lose track of my immediate surroundings.	**.58**	.13
MR12: When I listen to music my head moves along with the beat.	**.58**	−.07
MR13: When I hear music, my foot starts tapping along with the beat.	**.55**	.01
MR14: If the right song comes on, I have trouble following another person's conversation.	**.67**	−.02
MR15: If I close my eyes and listen to music, the rest of the world starts to fade away.	**.78**	−.07
Sensory-Processing Sensitivity (Aron & Aron, 1997)		
SPS1: To what extent . . . are you easily overwhelmed by strong sensory input?	−.09	**.53**
SPS2: . . . does your nervous system sometimes feel so frazzled that you have to get off by yourself?	.01	**.53**
SPS3: . . . do you seem to be aware of subtleties in your environment?	−.06	.20
SPS4: . . . do other people's moods affect you?	.12	**.44**
SPS5: . . . do you tend to be more sensitive to pain?	.02	.37
SPS6: . . . do you find yourself needing to withdraw during busy days, into bed or into a darkened room or any place where you can have some privacy and relief from stimulation?	.09	**.63**
SPS7: . . . are you particularly sensitive to the effects of caffeine?	−.06	.28
SPS8: . . . are you easily overwhelmed by things like bright lights, strong smells, coarse fabrics, or sirens close by?	−.01	**.47**
SPS9: . . . do you have a rich, complex inner life?	.28	−.05
SPS10: . . . are you made uncomfortable by loud noises?	−.09	.40
SPS11: . . . are you deeply moved by the arts or music?	**.50**	.00
SPS12: . . . are you conscientious?	.16	.12
SPS13: . . . do you startle easily?	.11	**.44**
SPS14: . . . do you get rattled when you have a lot to do in a short amount of time?	−.02	**.67**
SPS15: . . . when people are uncomfortable in a physical environment do you tend to know what needs to be done to make it more comfortable (like changing the lighting or the seating)?	.18	.02
SPS16: . . . are you annoyed when people try to get you to do too many things at once?	.07	**.46**
SPS17: . . . do you try hard to avoid making mistakes or forgetting things?	.00	.38
SPS18: . . . do you make a point to avoid violent movies and TV shows?	−.14	.35
SPS19: . . . do you become unpleasantly aroused when a lot is going on around you?	.05	**.64**
SPS20: . . . does being very hungry create a strong reaction in you, disrupting your concentration or mood?	.16	.17
SPS21: . . . do changes in your life shake you up?	.12	**.53**
SPS22: . . . do you notice and enjoy delicate or fine scents, tastes, sounds, and works of art?	**.43**	.09
SPS23: . . . do you find it unpleasant to have a lot going on at once?	.11	**.49**
SPS24: . . . do you make it a high priority to arrange your life to avoid upsetting or overwhelming situations?	.04	**.50**
SPS25: . . . are you bothered by intense stimuli, like loud noises or chaotic scenes?	−.11	**.53**
SPS26: . . . when you must compete or be observed while performing a task, do you become so nervous or shaky that you do much worse than you would otherwise?	.03	**.41**
SPS27: . . . when you were a child, did your parents or teachers seem to see you as sensitive or shy?	−.22	.37

Note. Loadings greater than .4 are in bold. MR = Musical Reactivity; SPS = Sensory-Processing Sensitivity. The Sensory-Processing Sensitivity items are from "Sensory-Processing Sensitivity and Its Relation to Introversion and Emotionality," by E. N. Aron and A. Aron, 1997, *Journal of Personality and Social Psychology, 73,* p. 352. Copyright 1997 by American Psychological Association.

(*Appendix continues*)

Table A3
Individual Question Loadings From Outcome Variable Factor Analysis in Study 4

Questionnaire item	Factor 1: Self-Esteem	Factor 2: Ingroup Identification	Factor 3: Belonging Motivation
Rosenberg Self-Esteem (Rosenberg, 1965)			
RSE1: On the whole, I am satisfied with myself.	**.78**	.06	−.10
RSE2: At times, I think I am no good at all. (R)	**.60**	.12	−.05
RSE3: I feel that I have a number of good qualities.	**.80**	−.15	.18
RSE4: I am able to do things as well as most other people.	**.72**	−.11	.04
RSE5: I feel I do not have much to be proud of. (R)	**.70**	−.07	−.02
RSE6: I certainly feel useless at times. (R)	**.68**	.02	.01
RSE7: I feel that I am a person of worth, at least on an equal plane with others.	**.68**	−.07	.01
RSE8: I wish I could have more respect for myself. (R)	**.58**	.01	−.24
RSE9: All in all, I am inclined to feel that I am a failure. (R)	**.76**	.02	.13
RSE10: I take a positive attitude towards myself.	**.71**	.12	−.02
Ingroup Identification			
ID1: To what extent do you feel pride when learning of the accomplishments of other University of Colorado students?	.10	**.58**	.07
ID2: To what extent do you dislike those people who attend the University of Nebraska?	−.07	.36	−.18
ID3: How much do you have in common with other students who attend the University of Colorado?	.28	.39	.09
ID4: How important is being a University of Colorado Buffalo to you?	.07	**.69**	−.08
ID5: To what extent do you agree with the following statement? "When I interact with others, I tend to think of myself as a University of Colorado student."	.14	**.61**	.03
ID6: How often do you wear clothing associated with the University of Colorado (e.g., CU sweaters, caps, shirts, etc.)?	.02	**.65**	.00
ID7: How much does being a University of Colorado student say about who you really are?	−.11	**.87**	.04
ID8: If you had a child who was considering attending the University of Colorado how disappointed would you be if they chose to get a degree from another university?	−.19	**.56**	−.12
ID9: To what extent do you agree with the following statement? "Knowing that I am a University of Colorado student tells others a lot about me."	−.09	**.72**	.11
Ingroup behavior: Ingroup bias in resource dilemma task point allocations	−.02	.24	.04
Need to Belong (Leary et al., 2012)			
NTB1: If other people don't seem to accept me, I don't let it bother me. (R)	−.27	−.01	**.45**
NTB2: I try hard not to do things that will make other people avoid or reject me.	.02	−.08	**.44**
NTB3: I seldom worry about whether other people care about me. (R)	−.05	.06	.22
NTB4: I need to feel that there are people I can turn to in times of need.	.07	.22	.28
NTB5: I want other people to accept me.	.09	−.01	**.63**
NTB6: I do not like being alone.	.15	−.01	**.54**
NTB7: Being apart from my friends for long periods of time does not bother me. (R)	.08	.02	.37
NTB8: I have a strong need to belong.	.02	.00	**.78**
NTB9: It bothers me a great deal when I am not included in other people's plans.	−.09	−.05	**.71**
NTB10: My feelings are easily hurt when I feel that others do not accept me.	−.13	.06	**.59**

Note. Reverse coded items are indicated with an (R). These items were recoded before being entered into the factor analysis. Loadings greater than .4 are in bold. RSE = Rosenberg Self-Esteem; ID = Ingroup Identification; NTB = Need to Belong. Rosenberg Self-Esteem is from *Society and the Adolescent Self-Image* (p. 51), by M. Rosenberg, 1965, Princeton, NJ: Princeton University Press. Copyright 1965 by M. Rosenberg. Need to Belong is from "Individual Differences in the Need to Belong: Mapping the Nomological Network," by M. R. Leary, K. M. Kelly, C. A. Cottrell, and L. S. Schreindorfer, 2012 (http://people.duke.edu/~leary/scales.html). Copyright 2012 by M. R. Leary, K. M. Kelly, C. A. Cottrell, and L. S. Schreindorfer.

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