



# Computational Language Analysis Reveals that Process-Oriented Thinking About Belonging Aids the College Transition

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Inequality in college has both structural and psychological causes; these include the presence of self-defeating beliefs about the potential for growth and belonging. Such beliefs can be addressed through large-scale interventions in the college transition (Walton & Cohen, 2011; Walton et al., 2023) but are hard to measure. In our pre-registered study, we provide the strongest evidence to date that the belief that belonging challenges are common and tend to improve with time (“a process-oriented perspective”), the primary target of social-belonging interventions, is critical. We did so by developing and applying computational language measures to 25,000 essays written during a randomized trial of this intervention across 22 broadly representative US colleges and universities (Walton et al., 2023). We compare the hypothesized mediator to one of simple optimism, which includes positive expectations without recognizing that challenges are common. Examining the active control condition, we find that socially disadvantaged students are, indeed, significantly less likely to express a process-oriented perspective spontaneously, and more likely to express simple optimism. This matters: Students who convey a process-oriented perspective, both in control and treatment conditions, are significantly more likely to complete their first year of college full-time enrolled and have higher first-year GPAs, while simple optimism predicts worse academic progress. The social-belonging intervention helped distribute a process-oriented perspective more equitably, though disparities remained. These computational methods enable the scalable and unobtrusive assessment of subtle student beliefs that help or hinder college success.

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# Computational Language Analysis Reveals that Process-Oriented Thinking About Belonging Aids the College Transition

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Main Text

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## **Abstract**

Inequality in college has both structural and psychological causes; these include the presence of self-defeating beliefs about the potential for growth and belonging. Such beliefs can be addressed through large-scale interventions in the college transition (Walton & Cohen, 2011; Walton et al., 2023) but are hard to measure. In our pre-registered study, we provide the strongest evidence to date that the belief that belonging challenges are common and tend to improve with time (“a process-oriented perspective”), the primary target of social-belonging interventions, is critical. We did so by developing and applying computational language measures to 25,000 essays written during a randomized trial of this intervention across 22 broadly representative US colleges and universities (Walton et al., 2023). We compare the hypothesized mediator to one of simple optimism, which includes positive expectations without recognizing that challenges are common. Examining the active control condition, we find that socially disadvantaged students are, indeed, significantly less likely to express a process-oriented perspective spontaneously, and more likely to express simple optimism. This matters: Students who convey a process-oriented perspective, both in control and treatment conditions, are significantly more likely to complete their first year of college full-time enrolled and have higher first-year GPAs, while simple optimism predicts worse academic progress. The social-belonging intervention helped distribute a process-oriented perspective more equitably, though disparities remained. These computational methods enable the scalable and unobtrusive assessment of subtle student beliefs that help or hinder college success.

## **Significance Statement**

We develop the first scalable, language-based measures to assess students’ perspectives on their college transition, providing a critical window into belief systems important for college success, and thereby upward mobility. In developing these measures with a broadly representative sample, we document a pervasive inequality in critical beliefs that underlie students’ experience of belonging in college. Moreover, because these automated measures are readily available, proximal, and unobtrusive, they can inform and improve efforts to disseminate adaptive beliefs in order to mitigate college inequality.

## Introduction

It is now known that brief exercises targeting how students make sense of their college transition can have lasting impacts on their success, even years later (1, 2). These exercises are significant because they can be implemented at a low cost at scale, reducing intergroup inequality (3, 4). However, no work to date has measured the very constructs believed to mediate these interventions' effects. Scalable measures are needed for confirming the role of underlying beliefs in student outcomes and for detecting intergroup disparities in these beliefs. In this pre-registered study, we develop such measures using natural language processing, to investigate adaptive beliefs about the college transition in data from 25,000 students.

College success is a critical pathway to upward mobility for millions of Americans. Yet, this path is not equally accessible to all (5, 6). Beyond structural barriers (7–10), psychological forms of privilege also contribute to inequality. Students from socially disadvantaged backgrounds often lack access to belief systems that help them navigate common challenges in school, such as viewing test anxiety as a potential asset (11) or having a growth mindset about intelligence (12). Students' sense of belonging stands out as particularly crucial for college success. Feeling included, valued, respected, and able to contribute to the college environment strongly predicts students' health, well-being, persistence, and academic performance (13–19). However, inequality in belonging is stark: Students from social groups that have been historically excluded from higher education often face the question “Can people like me belong here?” (20). This perspective can turn everyday challenges into perceived evidence of a permanent lack of belonging, leading to disengagement and perpetuating inequality in college outcomes (20–23).

In the present study, we focus on beliefs that help students overcome belonging challenges. Specifically, when students are offered the idea that challenges to belonging are normal in the college transition and improve with time (henceforth referred to as a *process-oriented perspective*), they can maintain their sense of belonging as they face everyday challenges, and ultimately persist and perform better in college (20–23). This relationship is causal — based on experimental evidence from large-scale social belonging interventions that convey this process-oriented perspective about belonging (1, 2). These interventions bring greater benefits to students in groups that have faced historic and contemporary exclusion in higher education, including racial-ethnic minority students, first-generation college students, and women in male-dominated STEM fields, thus helping to close achievement gaps (4, 20–22, 24). Advances in intervention delivery now allow these exercises to be implemented at an institutional scale for a marginal cost (3, 4).

However, there is a key missing ingredient from social-belonging interventions: Valid measurement of constructs thought to mediate the beneficial effects of the interventions. Measures are needed to confirm the role of these beliefs in the college

transition, reveal intergroup inequalities, and evaluate the effectiveness of specific policies and interventions. Ideally, these measures would assess beliefs in real-life settings, unobtrusively and at scale, integrated into intervention exercises.

Past research has documented intergroup inequality in critical beliefs in education using in-depth interviews and self-report surveys (11, 12, 20, 21, 25). However, these methods are limited by what people are aware of and willing to report (26, 27). Additionally, stand-alone assessments are time-consuming, reducing their practical utility. In the case of belonging, researchers have measured outcome beliefs (e.g., “I feel like I belong” (2, 13)); anticipated belonging (4); the degree of contingency students perceive in their belonging (belonging uncertainty, e.g., “When something bad happens, I feel that maybe I don’t belong at [school name]”, (20, 21)), and this observed contingency (i.e., in laborious daily-diary assessments, (20–23)). What has not been assessed are the critical underlying beliefs thought to be responsible for improvements in academic performance: Viewing challenges to belonging as normal and as improving with time in the school transition. Distal metrics, such as achievement, do not substitute: they take time to unfold, are influenced by many factors, and are not directly informative of the success of an intervention in addressing the underlying psychological process. The lack of scalable, proximal measures leaves ambiguity about how belonging interventions work and limits the ability to quickly evaluate their effectiveness for different groups.

The primary goal of this pre-registered study is to provide such measures. By analyzing essays from the largest trial of the social-belonging intervention conducted to date (22 U.S. colleges and universities,  $N=25,000$ ; (3)), we develop computational measures of a process-oriented perspective on the college transition. In focusing on students' open-ended writing, we do not assume that students are fully aware of these underlying beliefs or able to report them directly. We test for intergroup inequality in this index in students' spontaneous expressions in the active control condition; assess its predictive relationship with critical markers of progress in the first year of college (full-time completion rates, grade point average [GPA]); and evaluate whether the social-belonging intervention reduces inequality in these beliefs. We compare these results to a competing hypothesis: that *simple optimism*, without recognizing common challenges, mediates the effects of the intervention (28–30). Our approach follows research questions and analytic methods documented in our pre-registration (see *Methods*).

## Results

***Summary of Data.*** We use data from a large-scale social-belonging intervention (3), , which included more than 25,000 students enrolled in 22 colleges randomized to a social-belonging and active control exercise completed in the summer before they began their first year (see *SI Appendix*). This institutional sample reasonably represents 749

4-year institutions in the United States. The treatment condition described worries about belonging in the transition to college as normal for all students and as improving with time, whereas the active control condition focused on adjustment to the physical environment of college, including the campus, region, and weather. This focus permits students to articulate a process-oriented perspective about the college transition without specifically encouraging this view. Thus, it allows us to assess intergroup inequality in this way of thinking absent treatment, while the condition comparison allows us to assess whether and to what extent this shifts with the social-belonging exercise. The data includes “saying-is-believing” essays designed to help students take up and personalize the generic condition-specific message for themselves (20, 31, 32). We link these essays to key measures of college progress, including full-time enrollment GPA over the first year of college, thus enabling tests of predictive validity.

***Automatic computational annotation.*** We used natural language processing to detect the presence or absence of process-oriented or simple optimism in the 25,000 saying-is-believing essays. We define a process-oriented perspective as the combination of two ideas — that potential worries about belonging in the college transition are (1) common and (2) temporary. In contrast, we define simple optimism as positive expectations about the college experience without recognizing common challenges.

In the first step, we developed a codebook, iterating through nine versions, grounded in psychological theory and subtle language patterns observed in our data (see *SI Appendix*). Next, from 156 candidates, we carefully selected a diverse set of six undergraduate annotators (representing intersecting identities in terms of gender, race/ethnicity, first-generation status), thus helping ensure that these subjective constructs are recognized and interpreted by people with recent, lived experiences related to belonging in college (33, 34). After three rounds of training using the finalized codebook, the annotators labeled a random sample of 1,200 essays. In a third step, we used these annotations as labels in supervised machine learning to train a computational model to reproduce these annotations, based on the deep contextual representations of the language occurring in the essays (using a fine-tuned RoBERTa model (35), see *Methods* and *SI Appendix*). We observed substantial agreement between the human and computational annotations (see *Methods*). Finally, in the fourth step, we applied the computational models to derive annotations for all 25,000 essays, which form the basis of primary analyses.

### **Language markers of a process-oriented perspective and simple optimism**

To confirm the validity of our methods, beyond the substantial agreement between the automated and human annotations observed in step three (*Methods*), we sought to investigate if the computational annotations captured the subtle psychological themes identified in past theory. Machine-learning models based on contextual embeddings are

non-trivial to inspect directly, instead, we chose a straightforward language analysis method (“differential language analysis”; (36, 37)) to determine the words and phrases that statistically distinguish essays automatically annotated for the themes from those without (see Table 1). That is, we compared our data-driven “open vocabulary” approach with a “closed vocabulary” dictionary-based approach that is customarily used for psychological language analysis, namely the Linguistic Inquiry and Word Count (LIWC; (38)) (see Table 2).

In general, we observed language patterns matching our a priori theoretical understanding of the themes, lending face validity to the automated coding. First, simple optimism was expressed as excitement and anticipation about the college experience (e.g., “excited”, “forward”, “new people”, “ready”, “great”, “cannot wait to”), which was consistent with words in the LIWC positive emotion dictionary ( $B = .26, P < 0.001$ ).

Second, *commonality* was associated with words like “common”, “common among”, “everyone feels”, “typically feel,” and “not the only”. This language is also reflected in the “cognitive processes” dictionary of LIWC,  $B = .15$ , which includes the use of more comparisons as a subdictionary (LIWC,  $B = .09$ , all  $P$ 's  $< 0.001$ ).

Third, language associations with *temporariness* were largely similar to those associated with *commonality* except that they included more references to time orientations (LIWC:  $B = .19, P < 0.001$ ). Strongly associated words and phrases include “time”, “eventually”, “get used”, “takes time”, “after a while”, and “first few”.

Beyond these face-valid patterns, two other language patterns are noteworthy across emotions and pronouns. First, while simple optimism was strongly associated with positive emotions, essays with commonality were associated with negative emotions (LIWC,  $B = 0.14$ ), including anxiety (LIWC,  $B = 0.16$ , all  $P$ 's  $< 0.001$ ). This pattern is consistent with the inference that these essays anticipate the commonality of negative emotional experiences.

Second, differences in the use of pronouns are among the most well-studied language patterns (39). Increased use of first-person singular pronouns (“I,” “me,” “mine”; LIWC I category) generally indicates increased attention on the self, often in a maladaptive or vulnerable fashion (40). Third-person singular pronouns (“we,” “our”; LIWC WE category) indicate connection to a group, often in an adaptive fashion (41). We observed essays with *simple optimism* to include notably more self-references (LIWC I:  $B = 0.28$ ) and fewer “we”-references (LIWC WE;  $B = -0.11$ , all  $P$ 's  $< 0.001$ ). *Commonality* and *temporariness* showed the opposite pattern, with more “we” (LIWC WE,  $B = 0.15$  and  $B = 0.11$ , respectively) and fewer “I” references (LIWC I,  $B = -0.18$  and  $B = -0.19$ , all  $P$ 's  $< 0.001$ ). Both *commonality* and *temporariness* were also associated with more social words (LIWC Social,  $B = 0.27$  and  $0.19$ , respectively,  $P$ 's  $< 0.001$ ), supporting the inference that both reflect a stronger social orientation.

These language patterns lend face validity to the automated annotation of the three themes. They paint a picture in which essays coded as expressing *simple optimism*





<p>Belonging concerns are <b>temporary</b></p>	<p>The writer communicates an understanding that challenges to belonging are not permanent.</p>	<p>One of my worries going into college is getting along with my roommates. I have plenty of close friends going to [College Name] so i have no worries about meeting people. Most people worry about their roommates because they will be the ones you spend the most time with. <b>I believe people grow more comfortable over time because they adjust to the setting and how people are.</b> Students can meet more people to feel more at home.</p>	
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**Table 1.** Definition, examples, and correlational word clouds for each of the three lay theory themes. Essays do not need to mention belonging explicitly to be coded for commonality and temporariness; annotators were asked to look for themes that may impact belonging (e.g., fitting in, feeling at home). Essays were combined across the treatment and control conditions and the themes were automatically annotated using classifiers fine-tuned on manually labeled essays (*Methods*). Resulting annotations were binary for each theme (0=absent, 1=present). Differential word clouds show the words and phrases most associated with each theme, with word size representing the association strength (beta coefficient) (controlling for student gender and high school standardized test score as covariates, following (3)) and word color representing their relative frequency (from gray [rare] to blue to red [most frequent]) following (36). All words and phrases shown are significantly associated with the themes controlling for multiple comparisons (See *SI Appendix*).

Dictionary		Simple optimism		Commonality		Temporariness	
		beta	p	beta	p	beta	p
Social processes		-0.13	0.000	0.27	0.000	0.19	0.000
Time orientations		-0.03	0.000	-0.06	0.000	0.19	0.000
Cognitions	Cognitive process.	-0.15	0.000	0.15	0.000	0.16	0.000
	Insight	-0.14	0.000	0.10	0.000	0.21	0.000
	Comparisons	-0.14	0.000	0.09	0.000	0.14	0.000
Pronouns	I	0.28	0.000	-0.18	0.000	-0.19	0.000
	WE	-0.11	0.000	0.15	0.000	0.11	0.000
	YOU	-0.11	0.000	0.01	0.188	0.12	0.000
	THEY	-0.19	0.000	0.15	0.000	0.13	0.000
Emotions	Positive emotion	0.26	0.000	-0.07	0.000	-0.14	0.000
	Negative emotion	-0.01	0.285	0.14	0.000	-0.02	0.000
	Feel	-0.02	0.005	0.16	0.000	0.12	0.000
	Anxiety	0.01	0.082	0.15	0.000	-0.02	0.023

**Table 2.** The Linguistic Inquiry and Word Count (LIWC 2015) dictionaries which most distinguish themes. All associations (betas) are controlled for student gender and prior

achievement, and P-values are controlled for multiple comparisons. See *SI Appendix* for all LIWC dictionary results.

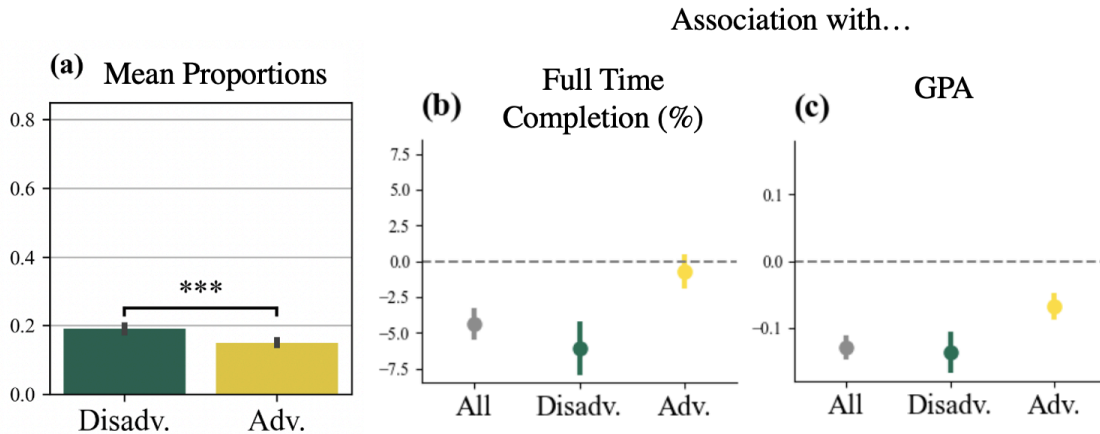
### **Group disparities in the expression of simple optimism and a process-oriented perspective**

To understand the relationship between students' social-group identity and their spontaneous understanding of the college transition absent intervention, we examine writing from the *control condition* (12,632 essays). We compared students from backgrounds disadvantaged in college (Black, Latinx and Native students and first-generation college students) and students from backgrounds advantaged in college (all others), following prior work (4, 22).

**Disadvantaged students were more likely to express simple optimism. In turn, simple optimism predicted worse academic outcomes.** Figure 1a shows that about 16% of control-condition students expressed simple optimism. Students from disadvantaged backgrounds were significantly more likely to express simple optimism than advantaged students (19% versus 15%;  $\chi^2(1) = 29.52$ ;  $P < 0.001$ ).

How did simple optimism predict the likelihood that students maintained full-time enrollment throughout their first year of college and their first-year GPA? We regressed these academic outcomes on the presence of simple optimism, controlling for student's gender and standardized college admissions exam score (SAT or ACT, converted to a common metric) following Walton et al. (2023), as well as essay word count, a major confounder in language analyses (*Materials and Methods*). We found that students who expressed simple optimism were 4.4 percentage points *less* likely to complete the first year full-time enrolled (SE=0.011,  $P < 0.001$ , Figure 1b) and obtained a first-year GPA that was 0.13 points lower (SE=0.018,  $P < 0.001$ , Figure 1c) than students who did not express simple optimism. These relationships, moreover, were stronger yet for students from disadvantaged backgrounds. The interaction between simple optimism  $\times$  disadvantaged status was significant both for full-time completion ( $B = -0.058$ , SE = 0.020,  $t(1) = -2.79$ ,  $P = 0.005$ ) and GPA ( $B = -.070$ , SE = 0.035,  $t(1) = -1.99$ ,  $P = 0.047$ ).

## Simple Optimism

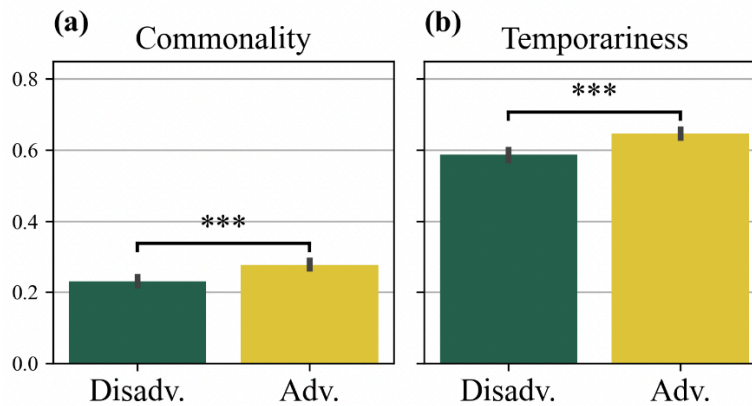


**Figure 1.** Panel (a) shows the proportion of students expressing simple optimism. Asterisks represent whether the difference, as measured by a chi-square test, is statistically significant by advantage status (\*\*\*:  $P < 0.001$ ). Panels (b) and (c) show the beta coefficients between expressing simple optimism and full-time completion and GPA, respectively, by advantaged status. Dots represent the coefficients and lines represent standard errors. Each dot represents a different regression. Models include the following covariates: essay word count, gender, and high school standardized test score (*Materials and Methods*). These analyses used control-condition data only.

### **Advantaged students were more likely to express a process-oriented perspective.**

About a quarter of control-condition students expressed the idea that potential belonging concerns are common (27%), two-thirds expressed the idea that belonging concerns are temporary (63%), and about one-fifth expressed the two jointly (22%). As Figure 2 illustrates, advantaged students were significantly more likely to spontaneously express these ways of understanding belonging (for commonality: 28% versus 23%; raw values;  $\chi^2(1) = 29.07$ ,  $P < 0.001$ ; for temporariness: 65% versus 59%;  $\chi^2(1) = 39.89$ ,  $P < 0.001$ ). Since 87% of essays that expressed temporariness also expressed commonality, commonality and the *joint* expression of commonality and temporariness yield similar results; we include analyses of these joint ideas in *SI Appendix*.

Together these results indicate that while a process-oriented view of the college transition is available to students even without a targeted intervention, there is significant inequality in these underlying beliefs. Notably, we document this inequality in a sample that reasonably generalizes to 749 4-year institutions in the United States.



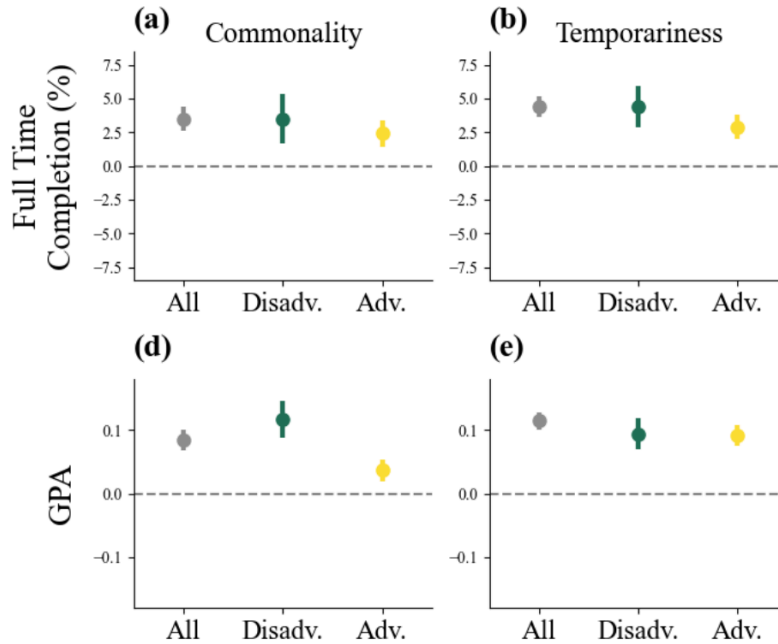
**Figure 2.** The proportion of students expressing the commonality (panel (a)) and temporariness (panel (b)) of belonging concerns, split by advantaged status. These analyses used control condition data only. Asterisks represent whether the difference, as measured by a chi-square test, is statistically significant by advantage status (\*\*\*:  $P < 0.001$ ).

**Articulating a process-oriented perspective predicted better academic outcomes. If anything, this was especially true for socially disadvantaged students.** Similarly to Figures 1b and 1c, we analyzed the extent to which a process-oriented view predicted academic outcomes, controlling for word count, gender and high school standardized test score.

As Figure 3a illustrates, control-condition students who expressed the idea that belonging concerns are common were 3.5 percentage points more likely to complete the first year of college full time ( $SE = 0.009$ ,  $P < 0.001$ ). They also earned first-year GPAs that were .084 points higher than students who did not (equivalent to 0.12 standard deviations,  $SE=0.016$ ,  $P < 0.001$ , Figure 3d). The interaction between discussing commonality  $\times$  disadvantaged status was significant for GPA ( $B = 0.077$ ,  $SE = 0.031$ ,  $t(1) = 2.53$ ,  $P = 0.012$ ) but not for full-time completion ( $B = -0.018$ ,  $SE = 0.018$ ,  $t(1) = 0.99$ ,  $P = 0.322$ ).

Similarly, students who wrote about belonging concerns as temporary were 4.4 percentage points more likely to complete the first-year of college full time (Figure 3b). Their first-year GPAs were also 0.114 points higher ( $SE=0.014$ ,  $P < 0.001$ , Figure 3e). The interaction between discussing temporariness  $\times$  disadvantaged status was not significant for either outcome (full-time completion:  $B = 0.021$ ,  $SE = 0.016$ ,  $t(1) = 1.32$ ,  $P = 0.186$ ; GPA:  $B = 0.005$ ,  $SE = 0.027$ ,  $t(1) = 0.20$ ,  $P = 0.842$ ).

Thus, students who spontaneously expressed a process-oriented perspective (i.e., absent intervention) did better in the first year of college, both in maintaining full-time enrollment and in earning a higher GPA, controlling for gender and incoming academic preparation. The positive relationship between GPA and discussing the commonality of concerns was greater for socially disadvantaged students.

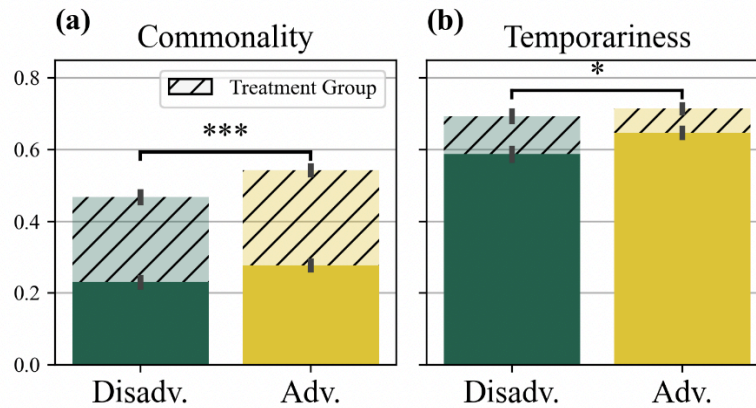


**Figure 3.** Beta coefficients between essay theme (commonality and temporariness of belonging concerns; independent variable) and academic outcomes (full-time completion, GPA; dependent variables) for different subgroups based on advantaged status. Dots represent the coefficients and lines represent standard errors. Each dot represents a different regression. Models include the following covariates: essay word count, student gender and high school standardized test score. The figure uses control-condition data only.

## Impact of the Social-Belonging Intervention

**The social-belonging intervention increased the expression of a process-oriented perspective and helped distribute it more equitably.** Students randomized to the social-belonging treatment were 25 percentage points more likely to express the idea that belonging concerns are common compared to control group students (52% vs 27%,  $\chi^2(1) = 1645.88$ ,  $P < 0.001$ ). They were also 8 percentage points more likely to express that belonging concerns are temporary (71% vs 63%,  $\chi^2(1) = 160.48$ ,  $P < 0.001$ ). Advantaged students were still more likely to write about the commonality of belonging concerns (47% for disadv. versus 54% for adv. students;  $\chi^2(1) = 63.51$ ,  $P < 0.001$ ; Figure 4a) and about temporariness (69% for disadv. vs 71% for adv. students,  $\chi^2(1)=5.99$ ,  $P < 0.05$ ; Figure 4b). However, in the case of temporariness, the increase from control to treatment was significantly greater for disadvantaged students (condition  $\times$  disadvantaged status interaction  $B = 0.045$ ,  $SE = 0.013$ ,  $t(1) = 3.54$ ,  $P < 0.001$ ), suggesting that the treatment helped distribute this construct more equitably. The increase was not significantly moderated by advantaged status for commonality ( $P = 0.118$ ).

The predictive relationship between each theme and academic outcomes held in the treatment condition, with the magnitude of these relationships similar to that observed in the control condition (*SI Appendix, Figure S4*).



**Figure 4.** The social belonging intervention increased the likelihood that students expressed a process-oriented perspective, especially the idea that belonging concerns are common. Asterisks represent whether the difference, as measured by chi-squared, is statistically significant by advantaged status in the treatment condition (\*:  $P < 0.05$ , \*\*\*:  $P < 0.001$ ).

## Discussion

Despite the key role of students' beliefs in college success (4, 11, 12, 25), there is a lack of scalable, proximal measures of underlying beliefs thought to promote a successful college transition. Using natural language processing to analyze participants' essays, we provided the strongest evidence to date for the role of the belief that challenges to belonging are common and temporary in the college transition. Efficient means of assessing these ideas at scale within intervention exercises is essential for implementing such interventions well.

To do so, we examined student essays collected as part of an intervention exercise. These essays offer potentially rich insight into how students are making sense of the college transition. They also allow us to develop measures that do not rely on student self-reports, which can be burdensome to students and institutions and depend upon the ability and willingness of students to report subtle underlying psychological processes. Integrating classic insights on the attributional processes at the heart of psychological exercises that seek to help students make sense of challenges in college productively (20, 42) and interactive procedures by which modern-day interventions are implemented (i.e., saying-is-believing tasks), we demonstrate the potential of computational methods to facilitate proximal measures of these underlying beliefs.

Our pre-registered study yields four key results, each with implications for psychological research and educational interventions. First, we show that we can build scalable language-based measures that face-validly capture the subtle psychological constructs targeted by “wise” interventions. Since these measures are based on essays collected from the intervention themselves (20, 31, 32), they require no extra time to

collect. Such language-based measures, when designed well, can serve as early and unobtrusive indicators of the effectiveness of specific implementations of educational interventions in affecting proximate processes (43, 44). They provide an alternative to survey items that require both time and a high level of self-insight in students. Furthermore, they enable a nuanced comparison across experimental conditions that incorporate similar writing tasks, informing finetuning.

Second, we show that expressing a process-oriented perspective varies by social advantage. Black, Latinx and Native students and first-generation college students were more likely to express simple optimism and less likely to express a process-oriented perspective about the college transition as compared to their advantaged peers. While past research has documented intergroup inequality in students' levels of belonging in college (12), we show that these same groups are less likely to enter college with the process-oriented perspective that can help students persist through challenges and develop their belonging over time.

Third, validating this measure and confirming past theory, we find that expressing simple optimism predicted worse academic outcomes over the first year of college, especially for socially disadvantaged students, and that a process-oriented perspective predicted better academic outcomes for all students. While prior work has shown that *offering* these beliefs to students can promote persistence and achievement in college, especially among socially disadvantaged students (3, 21, 42), we show that *expressing* these beliefs predicts greater persistence and achievement. At a higher level of analysis, these results confirm that it is not simple positive thinking alone that supports a better transition for students; it is ways of thinking that help students anticipate and empower them to overcome predictable challenges in this transition.

Fourth, we find that the belonging treatment increased the likelihood that students expressed a process-oriented perspective mitigating intergroup inequality, though some psychological inequality remained. This finding provides direct evidence that the intervention changed the underlying psychological mechanisms targeted by the belonging exercise (20). Furthermore, the methods provide a way of quantifying the effectiveness of the treatment, including in reducing group differences.

Overall, our work serves as a case study for how computational methods can be leveraged to capture subtle but powerful underlying psychological constructs. This approach could inform the efficient implementation of psychologically “wise” interventions within and beyond education. For example, it can yield immediately available process measures to be used by researchers during pilot testing (e.g. to refine materials and essay prompts) or potentially by participants as a source of real time feedback during or after writing tasks. Our study adds to the growing body of work showing how computational measures can scalably surface rich psychological information expressed in human language (37, 45–51), revealing psychological inequality, and inviting approaches to reduce it (44, 52, 53).

## Limitations & Future Work

**Generalizability.** Although a process-oriented perspective and simple optimism are relevant to constructs beyond social-belonging (42), we do not know whether our computational measures would transfer directly to saying-is-believing essays implemented in other psychologically “wise” interventions or to other sources of text (e.g. daily diaries, social media posts). Future work should evaluate the generalizability of our measures to other datasets and adapt them as needed, which may require collecting new annotations. Such adaptation is also required for measuring other constructs that may seem related but are conceptually distinct from a process-oriented perspective such as growth mindset.

**Social disparities.** The binary categorization we used to distinguish students who are advantaged in college from students who are disadvantaged follows prior work (4, 22) but oversimplifies dynamic and intersectional processes, both across student identity groups and in interaction within diverse institutional contexts (3). We opted for this simplified comparison given that the primary goal of the paper is to demonstrate *one* application of our measure to study social inequality in the college transition. Conducting a more comprehensive analysis of social inequalities is a valuable direction for future research.

## Materials and Methods

Full methods are in *SI Appendix*.

**Data.** We used data from a large-scale social-belonging intervention described in (3). While the original study included three conditions, a standard social-belonging treatment, an active control condition, and a condition in which social-belonging materials were customized for each institutional context, we filtered out rows from the latter condition following (3). Thus, students within both the standard treatment and the active control conditions responded to the same experimental materials across their institutions. The original data also included an “invalid essay” label, flagging essays shorter than 40 words and ones coded by RAs as not meaningful. We filtered out these rows (9% of the original sample). Our analytic sample includes exactly 25,000 essays: 12,632 from the control and 12,368 from the treatment condition. The median length of essays was 108 words (mean=130.81, std=86.95). While the essays could not be released to protect student privacy, our analytic sample, including language-based predictions for themes, can be found at <https://osf.io/rpg9j/>.

**Pre-registration.** We preregistered the research questions, how the data were coded, the academic outcome measures and control variables (<https://osf.io/adbg8/>).

**Classifiers.** We used the 1,200 manually annotated essays to develop classifiers for our target constructs: commonality of belonging concerns (binary), temporariness of belonging concerns (binary) and simple optimism (binary). Simple optimism (i.e.,



optimism without acknowledging the commonality of challenges) was derived from two automated measures: optimism (continuous between 0-2) and the aforementioned commonality measure, as described below.

First, before training the models, we aggregated rater scores between the two raters. For binary features, we took the maximum of two raters' scores; that is, if either rater coded the essay for the construct being present, the essay was labeled as 1, otherwise 0. For optimism, we took the mean of the two raters' scores. Next, we fine-tuned RoBERTa classifiers on the processed annotations to predict labels for optimism, commonality and temporariness. To evaluate model performance, we combined the held-out test sets in a five-fold cross-validation setup. Models agreed substantially with human judgments: optimism (Spearman  $\rho = 0.70$ ,  $P < 0.001$ ), commonality (precision = 0.77, recall = 0.80, F1 = 0.79), temporariness (precision=0.79, recall = 0.87, F1 = 0.83). Finally, to capture *simple* optimism, we assigned essays a label of 1 that had a score of 1 or greater on the optimism scale and a score of 0 for commonality. We focused on commonality (rather than temporariness) because it was clearly conceptually distinct from simple optimism (see codebook in *SI Appendix*) and also less frequently mentioned by students. However, our results do not change substantively by adding “temporariness=0” to the definition of simple optimism.

**Regression analyses.** We conducted pre-registered ordinary least squares regression analyses to correlate automatically detected language features with outcomes. Outcome variables were collected and processed by (3). These were: first-year full-time completion (binary variable, indicating whether the student completed all terms in their first academic year at full-time status) and first-year weighted GPA (continuous variable, representing the average GPA point value of courses taken in the first year weighted by the number of credits each course conferred). We group data by “canonical advantaged status,” a binary variable defined in (3) as all Black, Latinx and Native students and all first-generation students. It is crucial to note that we do not see racial or ethnic groups as “disadvantaged” in their essence; rather, groups face group-based threats based on social contexts. Since essay length is a key confounding variable in language studies (i.e., language features are more likely to appear in longer writings), we control for the number of words in the essay. We additionally control for participant gender (based on self-report survey data and school-provided data, preferencing self-reported values) and standardized test score (ACT and SAT converted to a common metric) following the specifications described by (3).

We conducted two robustness tests (see *SI Appendix*). First, we removed all control variables. Second, we added college as a control variable. Predictive relationships with first-year academic outcomes were similar if not stronger as in primary analyses.

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**Supporting Information for:**

**Computational Language Analysis Reveals that Process-Oriented  
Thinking About Belonging Aids the College Transition**

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Supporting text  
Figures S1 to S4  
SI References

## Data

### Source Data

The text data we used for our linguistic analyses were generated within the treatment and active control activities ((1); see *Materials and Methods*). In each condition, student participants were asked to reflect on and write about the college experience. Participants were shown stories from older students about challenges they have faced and how they worked through these challenges and prompted to reflect on these stories and how they are making sense of relevant challenges. In the intervention condition, participants reflected on how concerns about belonging in college are normal and tend to get better with time. In the control condition, participants reflected on how students become familiar with the physical environment of their college, such as the campus, weather, and location, over time. Due to the controlled, experimental nature of the study, the prompts were structurally equivalent, differing only in substance, that is, their inclusion of psychologically relevant or irrelevant reflection material. For this reason, the texts produced by intervention and control participants are directly comparable.

The essay prompts, along with quotes from prior students, for the control and treatment conditions are shown below. For more information on the original study that produced the data set used in the present study (and on the data set itself), see (1).

#### Control Condition Quotes & Prompt

##### Current Students Survey: Representative Stories

Next you will read nine stories that illustrate the major findings of the Current Students Survey. These stories are representative of the responses of participating students. Stories have been edited for clarity. Please take your time and read these carefully.

I'm from a big city, so [SCHOOL NAME] was an adjustment for me. Where I'm from, there are lots of people everywhere, all the time. It is noisy most of the day (and night), and that obviously isn't true of [SCHOOL NAME]. At first, I really noticed the difference, but I've come to appreciate the opportunity to get away from noise when I want to. I think it is good for me to go to school here because it is easier to concentrate on my work when there isn't the bustle of a big city right outside my front door.  
- Sophomore, African American female

I think [SCHOOL NAME] is beautiful—I love the design of the campus and the look of some of the buildings. My whole first year I think I was conscious of being in such a physically interesting place. Now that I've spent more time here I think less about the campus and buildings themselves. I guess that is natural—it isn't new to me anymore. But still, when I'm reminded of it, I am impressed again with how unique the look of [SCHOOL NAME] is.  
- Junior, White female

My first year at [SCHOOL NAME] I was not prepared for how long the cold weather lasted – winter seemed to start early and end late and the wind was so cold. I had to get a warmer winter coat and better boots. But now I'm prepared for whatever the winter is like and have dealt better with the weather since then.

- Sophomore, White male

I didn't know how I would like living in [CITY NAME]. So far in my college experience it hasn't mattered as much as I thought it would have. I've been so busy at [SCHOOL NAME] that I haven't ventured off-campus that much. But when I do, I've been pleased to find some interesting places to go and fun things to do outdoors.

- Junior, African American male

I think [SCHOOL NAME]'s campus is unique. I am always impressed by the natural surroundings especially near the bridge. I love studying in the [BUILDING NAME] or even just walking on the sidewalk near historic [BUILDING NAME] on my way to or from class. Freshman year, I would sometimes go out of my way to walk to the sculptures or to [BUILDING NAME] to walk by all the different trees and plants. Now that I'm more accustomed to campus, I don't wander around as much. Whenever I have visitors, though, I make time to show them all my favorite spots around campus. - Senior, Asian American female

Having grown up on the West Coast, I knew that [SCHOOL NAME] would be different from where I'm from. I wasn't sure what it was going to be like to live in [STATE NAME]. Overall I've really enjoyed being at [SCHOOL NAME] and living in [CITY NAME]. Though there was a lot that was new for me – from the weather to the food to getting around campus – now I am used to it and it all seems pretty normal.

- Sophomore, Hispanic male

Having grown up in the [CITY NAME] area, I didn't think that moving to [SCHOOL NAME] would be much of a change, but it was in some ways. I'd been on campus a number of times, but I hadn't really spent a lot of time. And it's not the same visiting as it is living here. It took some getting used to at first, but now I hardly give it any thought.

- Junior, White male

Initially, [SCHOOL NAME]'s campus felt pretty confusing to me. Freshman year, it took a while to figure out where all of the buildings and offices were. Now that I've been here for a while, I know where everything is, no problem. I like that [SCHOOL NAME] is small enough that I can get almost anywhere on campus in a few minutes, but also large enough to sometimes discover new places.

- Senior, Biracial (African American and White) female

I've really liked getting to know all about [SCHOOL NAME]. I enjoy attending the [FAIR NAME] at the beginning of the semester and [GROUP NAME] dance in November, or just going to the [BUILDING NAME] for Saturday breakfast when I have the time. I especially enjoy some of the [SCHOOL NAME] traditions. [SCHOOL NAME] and this part of [STATE NAME] is a place with an interesting history and I've enjoyed learning more about it. But now that I've been here for a while, it's not something on my mind as much as it was when I first got here.

- Senior, White female

### **Summary**

Many students described noticing the physical environment at [SCHOOL NAME] during their freshman year—the campus design and location, the weather, and what living in [CITY



[NAME] is like. However, with time students became familiar with the physical environment at [SCHOOL NAME].

Now we want to hear from you.

**Your Thoughts About Coming to [SCHOOL NAME]**

In an effort to further understand how this change takes place, we would like to ask you why you think this would be so—that is, why might students initially pay attention to the physical environment of [SCHOOL NAME] but ultimately become more familiar with it and pay less attention to it?

As you reflect and write, please illustrate your description with examples from your own thoughts about coming to college. You may also draw on your past experiences with other transitions (like starting going to high school or going to a summer program) and on the stories from the older students you just read, which are copied below.

*Note: Your response may be provided, anonymously, to incoming [SCHOOL NAME] students in future years to help give them a better understanding of what coming to college is like. The more you can describe what you anticipate experiencing the more future students will benefit. Thank you for your time and effort.*

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**Representative Stories**

[Quotes displayed at the bottom of the page for reference]

**Treatment Condition Quotes & Prompt**

Next you will read nine stories that illustrate the major findings of the Current Students Survey. These stories are representative of the responses of participating students. Stories have been edited for clarity. Please take your time and read these carefully.

When I got into college, I was so excited about becoming a student at such a great school. But sometimes I also worried I might be different from other students. And when I got to campus, sometimes it felt like everyone else was right at home, but I wasn't sure if I fit in. At some point, I realized that almost everyone comes to college unsure whether they fit in or not. It's ironic—everybody comes to college and feels they are different from everybody else when, really, in at least some ways we are all pretty similar. Since I realized that, my experience at college has been almost one-hundred percent positive.

- Sophomore, African American female

I love college and I wouldn't trade my experiences here for anything. I've met some close friends, I've had some fantastic experiences, and I've certainly learned a lot. Still, the transition to college can be difficult, and it was for me. My freshman year sometimes I didn't know what I was doing—I made a lot of casual friends at parties and other places but I avoided interacting with professors in class or going to office hours. I think I was intimidated by them. I also got some low grades early on, which stressed me out. But these things all got better over time. I began to make good friends through classes. And my grades got better as I started working in study groups and asking for help from professors. I even got involved in research with a professor. Now I am happier than I have ever been at college. It is really rewarding for me to feel like I belong in the intellectual community here.

- Junior, White female

Compared to other students, I worried that my high school wasn't so good and that maybe my high school classes hadn't prepared me well for college. When I got to campus, to be honest sometimes I thought some of my professors were scary. I thought they were critical and hard in their grading, and I worried about how they and other students would evaluate me. So I didn't speak much in class and I didn't want other people to read my papers. But after a while I began feeling more comfortable—I started to enjoy my classes more, and I found some close friends I trusted. I also became more comfortable speaking in class, and sometimes I asked my friends to look over my papers for me. And I saw that even when professors are critical, or their grading harsh, it didn't mean they looked down on me or that I didn't belong. It was just their way of motivating high-achieving students.

- Sophomore, White male

I had small, close-knit classes in high school, so I wasn't sure what kind of relationships I would have with professors in college. I came to a liberal arts school because I wanted smaller and more personalized classes, but still I worried that I'd be just another student and just another paper to grade. And it did take time to get used to interacting with professors. But eventually I saw that the professors really did care about me and were excited to talk with me. Freshman year, I was struggling with a writing assignment, so I went to office hours to talk with the professor. I showed him a draft and he was excited about the ideas. I mean, it wasn't well written yet but he showed me how I could take it to the next level. I realized that in college sometimes you have to reach out. Not everybody's going to be receptive all the time, but many professors are eager to work with students on subjects they love. Later, I ended up talking with another professor in my major about my interests. That ultimately led me to get involved in some research she was doing. I have just loved working with her outside the formal classroom. It is great to actually participate in cutting edge research!

- Junior, African American male

Initially my transition to college was pretty easy. Hanging out with friends in my dorm

was fun, and I met a lot of people early on. After Winter Break, things got harder because it felt like all my really good friends were at home and I didn't have friends like that at school. However, I decided to just give it time and let things fall into place. I got involved in extracurriculars, and I met people who had common interests and unique perspectives. I also got to know people in class as study partners who became close friends. I found a comfort zone by exploring my interests and taking the leap into an active life on campus. But this took time and before I found my niche here there were times when I felt quite lonely.

- Senior, Hispanic female

The summer before freshman year I was so excited about coming to college. But I was anxious too—it's a big transition. For me the most difficult part was coming from a situation in which I knew every student in high school for the past seven years to college where I didn't know one student yet. Once I got here, even though I met large numbers of people, I didn't have a small group of close friends. At first sometimes I felt I had to work to find lab partners and people to be in study groups with. I was pretty homesick, and I had to remind myself that making close friends takes time. But over time, in classes, clubs, and social activities, I have met other people, some of whom are now just as close as my friends in high school were.

- Sophomore, Biracial (African American and White) male

Before coming to college, I didn't worry much about classes and grades, but freshman year I felt unprepared for the workload and the differences in grading. It was a learning experience. After getting burned grade-wise several times and feeling stressed out in the process, I worried that I wasn't smart enough. Fortunately, a conversation with an upperclassman set me straight—he told me that everyone struggles at first. You have to learn how to study in college. I figured out how to budget my time more wisely, so I wouldn't have a huge crunch at the last second. And maybe even more important, I learned that when I get stuck on a problem or an idea it helps to talk with people—like a professor or someone in my class or even just a friend. Although my start was somewhat rocky, it has felt good to learn from my mistakes, and I am proud of the success I have had.

- Senior, Asian American male

As excited as I was to come to college, I must admit that part of me thought that I might not measure up to the other students. Early on, I bombed a test. It was the worst grade I'd ever received, and I felt terrible and isolated. But then, I found out I wasn't the only one. No one did well on that test. It was really hard—the professor was trying to set a high standard. He knew it'd be tough, but he knew that if we worked hard we could get to that level. It wasn't for some time that I believed that I was totally up to par and could really succeed here. But eventually I did, and college started to feel more like home. Though I still have doubts about myself sometimes, I know they're the kinds of things everybody feels on occasion.

- Junior, White female

When I think back to the summer before freshman year, I was incredibly excited about coming to college but I was also somewhat intimidated. Walking into classes for the first time freshman year was uncomfortable, especially small classes. I worried about whether I could hold my own with other students (some of whom were upperclassmen) let alone professors. In the beginning, sometimes class discussions felt over my head. But now I feel much more relaxed. I've realized it's not about holding your own. We all bring something to the discussion, a different perspective or new ideas. It can be easy to forget what you bring. And I saw that everybody here has a common goal—to share knowledge and to learn and grow to do cool things in the future. We are all a part of that. Now I feel much more confident participating in discussions, listening, and sharing my opinions.

- Senior, White female

### **Summary**

Many students described worrying at first about whether they fit in and belong in college. However, with time students reported making good friends, getting to know professors, and feeling more at home in college.

Now we want to hear from you.

### **Your Thoughts About Coming to [SCHOOL NAME]**

We know that you are excited to come to college. But we would also like to learn more from you and your classmates about the common worries and challenges students face when they come to college and how students overcome these challenges with time. That will help us help future students have a smoother transition to college.

In the space below please describe the thoughts, feelings, and worries you have as you prepare to come to [SCHOOL NAME]. Please describe:

- Worries you have about fitting in and belonging as you prepare to come to [SCHOOL NAME].
- Why these worries are likely to be common when students first go to college.
- Why students typically feel more at home on campus with time.
- What students do to feel more at home, e.g., as they get to know friends and professors.

As you reflect and write, please consider specific experiences you will have at [SCHOOL NAME] during your first year like living in a residence hall or fraternity, meeting new people, joining student groups, interacting with professors, and taking college classes. You may also draw on your past experiences with other transitions (like starting high school or going to a summer program) and on the stories from the older students you just read, which are copied below. Please take as much time as you like.

*Note: Your essay may be provided, anonymously, to incoming [SCHOOL NAME] students in future years to help give them a better understanding of what coming to college is like. The more you can describe the challenges you anticipate facing in coming to college and how you can respond to these challenges over time, the more future students will benefit. Thank you for your time and effort.*

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**Representative Stories**

[Quotes displayed at the bottom of the page for reference]

## Data Annotation

As noted in the main text, the classifiers we applied at scale were trained on a smaller set of manually annotated essays. The manual annotations were made by six undergraduate students implementing a novel, theory-driven coding protocol developed for this study. Grounded in social psychological theory and prior examination of student saying-is-believing essays (2, 3), we followed a design-thinking process to iterate through nine versions of the coding protocol before finalizing and applying it.

Once the coding instrument was finalized, we randomly sampled 1,200 essays (blocking by college, cohort year, and (dis)advantaged status) from the entire data set. We then recruited six undergraduate students from three four-year universities to serve as our manual annotators, providing the data to train our machine learning classifiers. We sought annotators who could relate to the perspectives of undergraduate students to maximize the likelihood that the psychological information under investigation was extracted from the text.

We asked the 156 interested students who responded to our recruitment email to self-report basic demographic information in order to use those variables in our selection of a generally representative sample of individuals with intersecting identities of race/ethnicity, gender, and first-generation status. To do this, we aimed to balance gender identity equally across annotators (i.e., three men and three women), and select one student from each of the following groups: White, continuing-generation; Asian, first-generation; Black, continuing-generation; Black, first-generation; Hispanic, continuing-generation; Hispanic, first-generation. After applying these criteria to the total interested students, the breakdown of eligible undergraduate annotators was as follows:

- Asian, first-generation, female (n = 5)
- Black, continuing-generation, male (n = 3)
- Black, first-generation, female (n = 6)
- Hispanic, continuing-generation, female (n = 3)
- Hispanic, first-generation, male (n = 1)
- White, continuing-generation, male (n = 10)

When the group contained more than a single individual, we randomly selected one within the group.

Procedurally, each essay was annotated by two different annotators. Before beginning the annotation process, all annotators underwent three rounds of training conducted by one of the protocol developers. For each round, the whole group met to discuss the protocol and its application to a sample of essays (5 essays for the first round, 10 for the second, and 12 for the third) and, through discussion, reached consensus on the appropriate codes to assign each essay.

We computed average pairwise inter-annotator agreement on the final sample (1,200 examples, each labeled by two annotators). Our goal was to optimize for diverse representation among our group of annotators, which was expected to lead to diverging interpretations of target themes based on their lived experiences. The average Spearman correlation coefficient was 0.43 ( $P < 0.001$ ) for optimism and the average Cohen's kappa score was 0.55 for commonality (avg. agreement = 81%) and 0.35 (avg. agreement = 67%) for temporariness. These inter-rater agreement scores are comparable to or higher than those obtained on similarly nuanced constructs related to appraisal and affect (4–6) and are expected in language analyses that require making contextual inferences about

the writer’s intention (7). The fact that the language prediction models trained on these annotations predict external outcomes (such as GPA and persistence) suggests that the methodological pipeline from human annotation to language-based automatic annotation has predictive validity.

### Coding Protocol

Below we show excerpts from the coding protocol that are relevant for the themes we focus on in the present paper. The protocol included additional constructs (eg. whether the essay mentioned social concerns, physical concerns, whether they discuss past experiences with transitions). These additional constructs were not fundamental to our definition of a process-oriented perspective and hence were excluded both from the pre-registration and the current paper.

Construct	<b>Optimism</b>
Core question	How much does the student express hopefulness/optimism that they will come to belong?
Description	Note that this code is NOT contingent on whether or not a student expresses a belonging concern. It is also NOT just general positivity about the future. It has to do specifically with statements concerning an expectation that in the future they will increase in their sense of belonging at the school.
Scale	<ul style="list-style-type: none"> <li>0. Not at all</li> <li>1. Somewhat</li> <li>2. A lot</li> </ul>
Example essays	<p>0: As a transfer student, I am mostly worried about encountering the same issues I had with my first college. I am worried that I will not make close friends, and I am worried that I will feel like an outcast during my time at my new college. I am also worried that I will arrive at my new college and feel like I made a mistake leaving my old college. \\\My initial transition to college was very difficult. I was not really thrilled with the university I had chosen to attend, but it was the best option I had academically, so I felt like I was doing myself a disservice by not attending. However, what I really wanted in a college experience was a bigger school, with a strong sense of school spirit and a strong sense of community across campus.</p> <p>1: As I prepare to be a freshman at [school name] the worries that I have derive from the fresh start that college provides. The past four years of high school I have grown to have a solid group of friends and places of sincere belonging within my school. As I leave this place of comfort, I am anxious about making true friends and finding my place at [school name]. / / In all honesty, it's always a bit awkward at the beginning-- meeting new friends, the first day of class, and going to the call-out meetings for clubs. After I take these initial steps out of my comfort zone, <b>I know good things will come and [school name] will start to feel more and more like home.</b> Ultimately, I know that the good won't come from sitting in my dorm watching Netflix, but instead by placing myself in sometimes uncomfortable situations, studying till midnight, and trying new things. / / Another aspect that I</p>

	<p>think about as I enter this next chapter is what I am being called to do to serve and spend my time doing. My sophomore year of high school the Lord revealed to me that Dance Marathon was where He needed me, but that may not be the same at Hope. <b>This lack of knowledge for the future leaves me anxious but excited.</b></p> <p>2: In high school, I went to two schools, a public school and a mathematics and science institution. At my public school, I had a lot of friends but not really any close ones, but at my second school, I had a small group of really good friends that I hang out with alot. I know that [school name] is a small college, but I am anxious to see how well I fit in. I think this is a common concern because coming from a public school into a private school is something that I have never done before. <b>However, I think once I am on campus for some time, I will become accustomed to a routine and with meeting friends and homework and socializing will come more natural to me. Once I meet friends and start to form those relationships, I will want to hang out and also bring those friends home to complete the experience of acceptance and comfort knowing that I have a group that I belong to.</b> Going to a summer program the summer of my Junior year helped prepare me for the transition to college because I was living in a college dorm, with community bathrooms, a computer lab, and all of the things to expect in a dorm at Indiana University. <b>Meeting all of the diverse individuals my age will allow me to connect to other people once I get on campus at [school name]. I will succeed at Hope College, while also building relationships that will last a lifetime.</b></p>
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Construct	<b>Common</b>
Core question	Does the student express an understanding that others also have belonging concerns?
Description	<p>The writer communicates that it is normal to have concerns about belonging in college. They demonstrate an understanding that many students have these worries. Keep an eye out for statements like “everyone is in the same boat.” That should usually (if not always) get a 1 for this code.</p> <p>They do not necessarily endorse the idea that everybody experiences belonging concerns (though this idea would also receive a code of 1).</p> <p>Note that the writer does not necessarily have to express their own worries about belonging. It is sufficient for them to point out that many others do.</p>
Scale	<p>0. No</p> <p>1. Yes</p>
Example	<p><b>1: I feel as though every student that is transitioning from high school worries about "fitting" in to the college life. This feeling is similar to kids moving from middle school to high school which allows me to understand that it really isn't about "fitting" in, but rather finding who I am. Everybody is on the same boat coming into college and I worry that I just want to find people similar to me. I also worry about being homesick which I believe every student that is away from home for the first time will feel. It'll be tough, but having less worries about fitting</b></p>



	<p>in and just working through trying to find friends that are common with you which will be there will make the transition easier and faster. My last worry is success in the classroom. I'm pretty open in class discussions and I don't worry about whether I can hold my own on those, my fear is being able to write well enough and succeed on tests. I think it will come down to building friendships with Professors and getting complete understanding about the goals we both want.</p>
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Construct	<b>Temporary</b>
Core question	Does the student describe belonging concerns as being temporary in nature?
Description	<p>The writer communicates an understanding that challenges to one's belonging are not permanent. They do not indicate that one will never come to belong. They improve over time. Note that the actual timeline of improvement will differ for students, so there is no expectation that the students will write about when specifically the challenges will get better, just that it will happen eventually.</p> <p>Note that the writer does not have to directly connect their own concerns to the temporary nature of belonging concerns. That is, they could say something like "other students' belonging concerns get better over time because they become more comfortable around their peers," and it would qualify as a 1 for this code.</p> <p>To be clear: The writer must be talking about belonging concerns being temporary in nature, not just any change process. For example, if they only talk about people getting used to the architecture of a new school, they should not get a 1 (because they don't talk about a belonging concern).</p> <p>Also note that it is not sufficient for the writer to say they "hope" that they will come to belong.</p>
Scale	<p>0. No 1. Yes</p>
Example	<p>1: I'm really excited to go to college because I have always wanted to branch out from my tight knit family. But then I have also never been away from home and from my family. I don't really worry socially because I'm very outgoing and it has always worked for me. But a lot of people are nervous and I want to be the person to unify others! <b>Home is wherever you make it so overtime as you meet people I assume that it will feel like home because of the people they surround themselves with.</b> I want to join extracurricular that interest me and i want to join clubs that i would never think of because I want to meet all sorts of people. I also want to increase my scholastic career in the best way possible to I can achieve my dreams and I know [school name] will be just the place for that.</p>

## **Details on Model Training and Validation**

As described in *Materials and Methods*, we fine-tuned RoBERTa (8) on the annotated dataset to develop our automated measures. For the two binary constructs (commonality and temporariness), we used a classification setup and for the continuous construct (optimism), we used a regression setup. Each of the three models was trained for 10 epochs, with a batch size of 8 and gradient accumulation steps of 2. The other parameters were set to default. We conducted five-fold cross-validation to evaluate model performance. To compute performance metrics, we combined predictions for the held-out test set (20%) from each of the five iterations. The models agreed substantially with human judgments: optimism (Spearman  $\rho = 0.70$ ,  $P < 0.001$ ), commonality (precision=0.77, recall=0.80, F1=0.79), temporariness (precision=0.79, recall=0.87, F1=0.83).

## Language Analyses

**Extraction of relative word and phrase frequencies.** We included in the analysis essays that had at least 50 words and thus could yield meaningful open-vocabulary language findings (following (9, 10), leaving  $n = 24,072$  essays for this analysis. We determined the relative frequency with which users used words (unigrams) using an open-source Python-based language analysis infrastructure (DLATK, [dlatk.wwpb.org](http://dlatk.wwpb.org); (11)) which handles emoticon-aware tokenization and feature extraction.

**LIWC Dictionary associations.** Using the DLATK codebase, we extracted the relative frequency of 73 dictionaries provided by Linguistic Inquiry and Word Count (LIWC) 2015 (12). For example, this allowed us to determine what fraction of an essay's words matched the *positive emotion* dictionary (e.g., 2.1% for a given essay).

Table 2 in the manuscript shows selected Linguistic Inquiry and Word Count (LIWC) 2015 dictionaries that most distinguish the three themes. The betas are derived in a covariate regression model simultaneously controlling for student gender and high school standardized test scores, following (1). One LIWC dictionary is regressed against one theme at a time (with the covariates). P-values associated with these regression coefficients are controlled for the number of LIWC features (73) using Benjamini-Hochberg correction for multiple comparisons.

**Words and phrases.** As a fully data-driven open-vocabulary complement to the dictionary methods, we determined which words and phrases were most associated with the automatically annotated themes (contained in Table 1 in the manuscripts) using Differential Language Analysis (Eichstaedt et al., 2013, Kern et al., 2016). Following the methods established in Eichstaedt et al., 2013, we shortlisted words to those occurring in at least 0.3% ( $=72$ ) of essays, and to phrases that met a Pointwise Mutual Information criterion of 4 (thus, were 4 times more likely to occur as a phrase compared to the random co-occurrence of the constituent words). This yielded a final feature set of 5,218 language features. Words and phrases were individually correlated against the automatically annotated themes (one at a time), again in a regression model controlling for student gender and high school standardized test scores as covariates, following (1).

**Differential word clouds** show the words and phrases most associated with each theme, in descending order of individual association, with word size representing the association strength (beta coefficient) and word color representing their relative frequency (from grey [rare] to blue to red [most frequent]) following (13). All words and phrases shown are significantly associated with the themes controlling for multiple comparisons using Benjamini Hochberg.

## Regression Analyses

We conducted pre-registered ordinary least squares regression analyses to estimate the relationship between our measured constructs and academic outcomes. Each observation represents a student. Following specifications on p. 33 of the Supplementary Material of (1), we use gender and high school standardized test score as covariates. Given that word count is a significant confounder in language analyses, we additionally control for this variable. Below we present analyses that augment and provide evidence for the robustness of our findings.

## Discussing Both Commonality & Temporariness

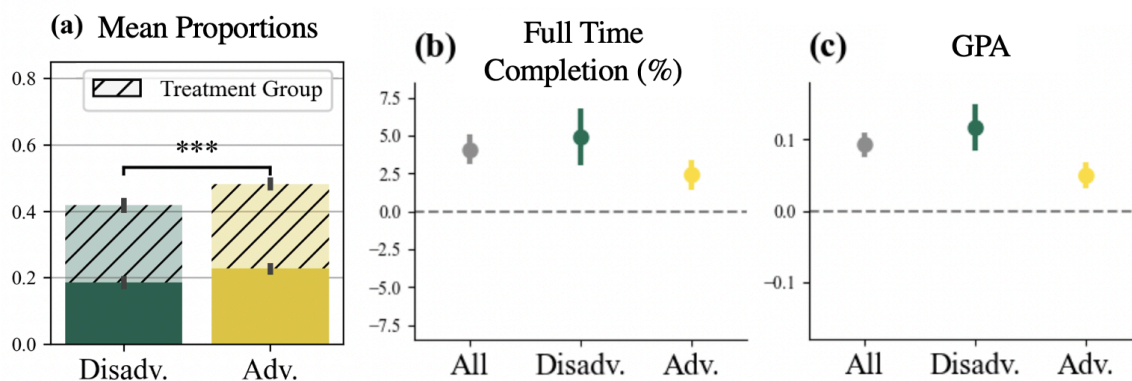
Given that we define process-oriented optimism as a combination of *commonality* and *temporariness*, we supplemented analyses examining these themes separately with analyses that combine these codes (i.e., when both commonality and temporariness are 1). Given that 87% of essays that mention commonality also mention temporariness (the reverse is not true for temporariness: only 51% of essays that mention temporariness discuss commonality), the results for commonality and those for the joint discussion of commonality and temporariness are very similar.

As Figure S1a shows, in the control group, advantaged students were significantly more likely to express commonality and temporariness jointly compared to disadvantaged students (23% versus 19%;  $\chi^2(1) = 27.09, P < 0.001$ ). The average percentage of students to express these ideas jointly increased from 22% to 46% in the treatment group ( $\chi^2(1)=1616.63, P<0.001$ ). The social disparity remained significant in the treatment condition (48% for advantaged students versus 42% for disadvantaged students;  $\chi^2(1)=45.99, P < 0.001$ ).

Discussing both the shared and transient nature of belonging concerns predicted a 4.1 percentage point increase in full-time completion rates (SE = 0.010,  $P < 0.001$ , Figure S1b) and a 0.093 increase in first-year GPA (SE = 0.017,  $P < 0.001$ , Figure S1c). The interaction between discussing these constructs x disadvantaged status was significant for GPA ( $B = 0.066, SE = 0.032, t(1) = 1.99, P = 0.046$ ) and positive but not significant for full time completion ( $B = 0.031, SE = 0.019, t(1) = 1.60, P = 0.110$ ).

## Commonality & Temporariness

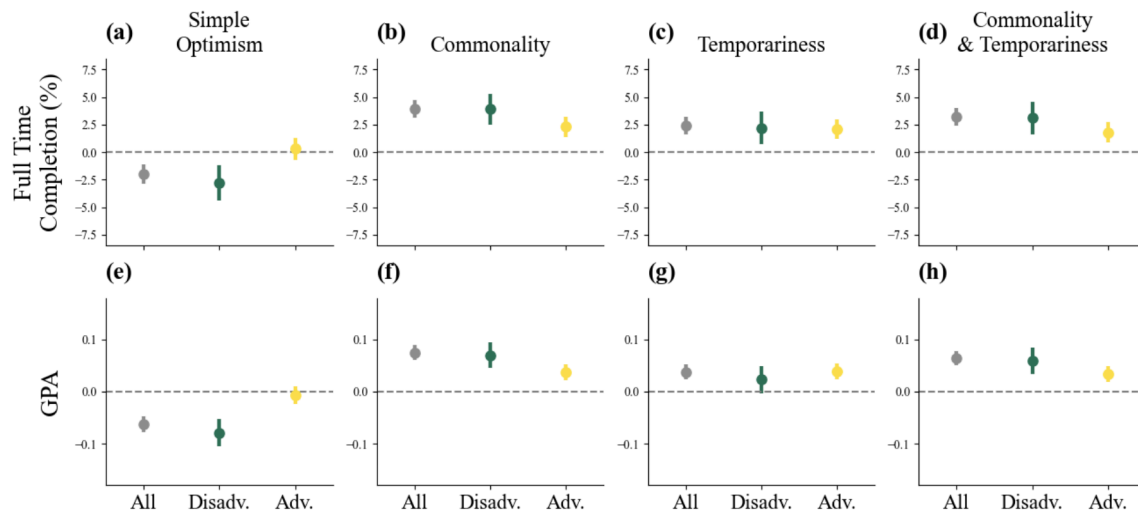
Association with...



**Figure S1.** Panel a) shows the proportion of students expressing both commonality and temporariness of belonging concerns in the control and treatment group. Asterisks represent that difference, as measured by a chi-square test, is statistically significant by advantage status both for the control and treatment group (\*\*\*:  $P < 0.001$ ). Panels (b) and (c) show the correlation coefficients between expressing commonality and temporariness and full-time completion rate and GPA, respectively, by advantaged status. Dots represent the coefficients and lines represent standard errors. Each dot represents a different regression. Models include the following covariates: essay word count, student gender, and high school standardized test score. Panels (b) and (c) analyses use control condition data only.

## Correlation Between Language Features and Academic Outcomes in the Treatment Condition

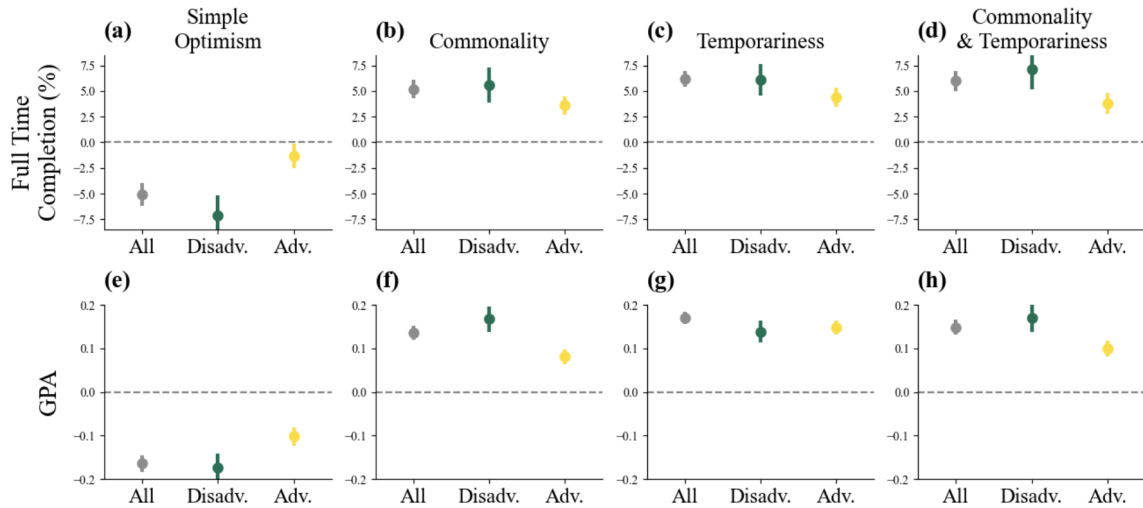
Predictive analyses using data from the treatment condition show analogous trends with academic outcomes as observed in the control condition (see Figure 3).



**Figure S2.** These plots represent the relationship between essay theme (simple optimism, commonality and/or temporariness of belonging concerns) and academic outcomes (full-time completion, GPA) by advantaged status within the social-belonging treatment condition. Dots represent the coefficients and lines represent standard errors. Each dot represents a different regression. Models include the following covariates: essay word count, gender and standardized test score.

## Robustness Test #1: Removing Control Variables

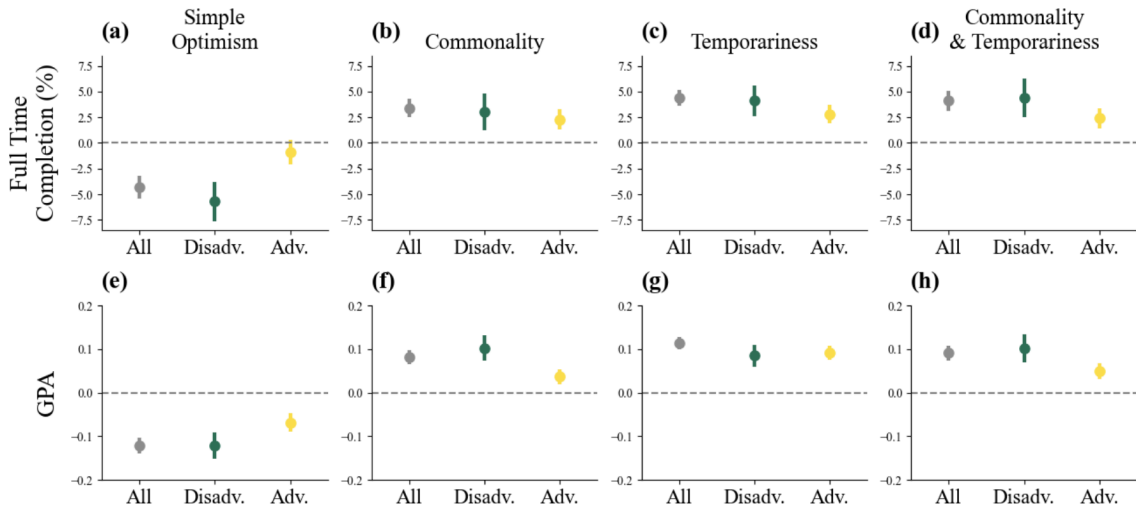
As a robustness test, we conducted the same regression analyses as in Figures 1 and 3 without control variables. The predictive results with academic outcomes are similar, if not stronger as analyses with control variables.



**Figure S3.** This plot represents the relationship between essay theme (commonality and/or temporariness of belonging concerns, simple optimism) and academic outcomes (full-time completion, GPA) by advantaged status. Dots represent the coefficients and lines represent standard errors. Each dot represents a different regression. Models include the language feature as a single predictor, with no control variables.

### Robustness Test #2: Adding College As A Control Variable

As a second robustness test, we conducted the same regression analyses as in Figures 1 and 3 while adding college as a covariate. The predictive results with academic outcomes are substantively the same as analyses without the college covariate.



**Figure S4.** This plot represents the relationship between essay theme (simple optimism, commonality and/or temporariness of belonging concerns) and academic outcomes (full-time completion, GPA) by advantaged status. Dots represent the coefficients and lines represent standard errors. Each dot represents a different regression. Models include the following covariates: essay word count, gender, standardized test score, and college.

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