Manipulating Temporal Expectations to Accelerate Healing After Cataract Surgery: A Randomized Controlled Trial

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March 2026

Abstract

Previous research has demonstrated that perceived time can objectively influence physiological outcomes, but these effects have been produced using false temporal feedback in controlled laboratory settings — an approach that cannot be directly extended to clinical practice. Drawing on the Embodied Models of Health (EMH) framework, which holds that beliefs shape health outcomes by orienting attention and expectation formation, the present study tested whether shifting patients' temporal expectations could influence actual post-surgical recovery. Patients undergoing bilateral cataract surgery were randomly assigned to a fast healing condition, in which they watched a preoperative video emphasizing faster-than-standard recovery timelines and completed daily check-in surveys designed to direct attention toward healing variability, or a standard healing condition, in which they received conventional recovery information and completed surveys unrelated to healing. Objective visual acuity was assessed at baseline and at 1-day, 1-to-2-week, and 3-month postoperative follow-ups. Group-level differences were directionally consistent with the hypothesis (the fast healing group showed larger improvements at every wave) but modest in magnitude. The theoretically motivated analyses, however, revealed an Attention × Sensitivity interaction consistent with the EMH framework's core prediction: among patients who internalized the faster expected healing times (high sensitivity), greater daily attention to healing variability predicted meaningfully faster recovery in visual acuity; among those who did not internalize the expectations (low sensitivity), attention to healing had little effect. These findings provide the first direct empirical evidence in a clinical population that attention functions as a belief-weighted mediator between psychological processes and physiological outcomes, and they extend prior laboratory demonstrations of mind-body unity to a real-world medical setting with practical implications for pre-operative communication and post-operative care.

JEL Classification: I12, I18, D91, C93

Keywords: mind-body unity, placebo effects, temporal expectations, cataract surgery, health beliefs, attention, expectations

Introduction

In 2023, Aungle and Langer published a study that found that experimentally induced wounds objectively healed faster the more time participants believed had passed, even though the true elapsed time was always the same (Aungle & Langer, 2023). Their paper is part of a relatively nascent field of inquiry within mind-body research that demonstrates perceived time has real physiological consequences independent of real time. Researchers have also found that perceived time independently influences blood glucose levels (Park et al., 2016), perceived sleep independently influences brain activity and cognitive function (Rahman et al., 2020), and perceived time independently predicts neuromuscular fatigue (Matta et al., 2025; Matta et al., 2024). In all such studies, researchers use false temporal feedback to produce the reported effect – an approach that is hard, if not impossible, to extend beyond the laboratory.

One way to think about the underlying mechanisms across these studies, however, is to think of perceived time as an input to expectation formation, with expectations ultimately producing the effects. We know from the voluminous literature on placebo effects that expectations are a fundamental driver of physiological functioning (Finniss et al., 2010; Geuter et al., 2017; Price et al., 2008; Wager & Atlas, 2015), so it stands to reason that effects similar to those produced by perceived time can be produced by shifting temporal expectations. *In other words, if we change how quickly someone expects a physiological process to unfold, we should be able to influence how quickly it actually happens.* That is the premise underlying the current study, which aimed to test whether manipulating patients' healing time expectations following cataract surgery actually changes how quickly they heal. This question builds on a large body of work on placebo effects.

Placebo effects, expectations, and health

For centuries, we have known that expectations and health are inextricably linked (De Craen et al., 1999; Finniss et al., 2010; Kaptchuk, 1998). Rigorous scientific study of this process, however, only got fully underway after Henry Beecher "discovered" the placebo effect and introduced randomized controlled trials (RCTs) to medical science (Beecher, 1955). Working as a medic during World War II, Beecher ran out of morphine while caring for injured soldiers, so he decided to pretend he was injecting morphine when in reality he was using saline. Much to his surprise, many of the soldiers responded to the saline as if it was morphine: they experienced real pain relief because they expected an analgesic effect. Beecher was not the first to observe that expectations fundamentally shape health – for example, Wolf (1950) famously told a 28 year old pregnant woman suffering from nausea that ipecac, a medication used to *induce* vomiting, would *alleviate* her nausea, which it then did – but he was the first to systematically document the phenomenon, quantify its effects across clinical contexts, and argue persuasively that patients' expectations should be treated as a central variable in medical science.

Beecher's work led directly to the study of "the pharmacology of placebo," which established that placebo treatments share many of the characteristics of actual drugs – e.g., peak effects, cumulative effects, carryover effects, and efficacy inversely related to severity (Lasagna et al., 1958). For the next two decades, although substantial research on placebo effects was conducted, the idea that they were a kind of subjective illusion remained (Enck et al., 2013; Kaptchuk & Miller, 2015). That started to change in meaningful ways as a result of three new developments in the field. One, researchers began to understand the neurobiology of placebo effects (Levine et al., 1978), which demonstrated that placebos work through biological mechanisms (i.e., that they are not subjective illusions). Two, Ader and Cohen demonstrated that conditioned expectations alone can shape immune function, giving rise to the field of psychoneuroimmunology (Ader & Cohen, 1975). Three, Langer and colleagues published several studies that underscored how simple differences in the ways we think can lead to substantial improvements in longevity and health (i.e., that the "placebo" phenomenon extends well beyond doctors' offices and hospitals) (Langer et al., 1990; Langer et al., 1975; Langer & Rodin, 1976; Rodin & Langer, 1977).

These three developments led to a proliferation of new research that made clear expectations about our health significantly shape the health we experience. Irving Kirsch's response-expectancy theory helped shift thinking to expectations as central mechanisms in placebo responses (Kirsch, 1985). Benedetti and colleagues uncovered diverse mechanisms underlying the effects of expectations on physiology (Benedetti & Amanzio, 1997) and demonstrated that hidden administration of active treatments is less effective (Benedetti et al., 2003), underscoring the central role played by expectations beyond inert treatments. While much of the early work involved mental health and pain, de la Fuente-Fernandez and colleagues showed that simply expecting medication for Parkinson's disease causes the brain to release a significant amount of dopamine, even though the patients only received a placebo injection (de la Fuente-Fernández et al., 2001). Moseley and colleagues found that sham knee surgery produced the same benefits as real knee surgery, demonstrating that expectations are fundamental to outcomes from invasive procedures as well (Moseley et al., 2002). Crum and Langer showed that simply expecting the benefits of physical exercise can produce those benefits, even when behavior remains unchanged (Crum & Langer, 2007). Kaptchuk and colleagues established that "open-label placebos" – placebos given to patients who know they are taking a placebo – can still produce real health benefits (Kaptchuk et al., 2010), providing evidence that placebo effects do not depend entirely on deception.

As the underlying science has advanced, and the breadth of psychological influences on physical health has become clearer, the stakes surrounding the principle of mind-body unity, first articulated in Langer et al. (1990), have grown. In previous work, we argued that the term "mind-body connection" is far more common than "mind-body unity," and that this subtle semantic difference obscures the breadth of psychological influences on health (Aungle & Langer, 2023). We recently proposed an Embodied Models of Health (EMH) theoretical framework for understanding how mind-body unity works in practice (Aungle, Matta, Chen, et al., 2026), which we formalized into a computational model in a complementary companion paper (Aungle, Matta, Loecher, et al., 2026); within the EMH framework, beliefs about how health works can become self-fulfilling by shaping attention allocation and expectation formation processes. Expectations are fundamental drivers of mind-body effects, and one way to understand the perceived time findings mentioned at the beginning of this paper is to think of perceived time as an input to expectation formation.

Experimental Design Overview

Given that the perceived time studies mentioned earlier occurred under the tightly controlled conditions of laboratories, a natural question arises – how can we extend these findings to real life, outside the lab? As we argued above, one way to do so could be to intervene on temporal expectations directly. In the present study, we explored this possibility in the context of patients recovering from cataract surgery.

Cataract surgery is one of the most common and standardized surgical procedures worldwide, with a highly predictable recovery trajectory and well-characterized time course of visual improvement (Grzybowski & Kanclerz, 2019). Patients are routinely given explicit information about what to expect during recovery, making healing timelines both salient and clinically relevant (e.g., National Health Service, 2025). At the same time, recovery unfolds over days to weeks – long enough for expectations to plausibly shape physiological processes, but short enough to measure objective outcomes with precision. The popularity of the procedure, its standardized nature, and the predictable recovery trajectory were all reasons we chose to focus on recovery from cataract surgery.

We employed a randomized controlled design to test whether experimentally manipulating healing time expectations following bilateral cataract surgery influences actual healing times. Consistent with our discussion of placebo effects above, which highlights that expectations are increasingly seen as a central variable across medical science, past research has found that expectations independently and significantly shape surgical outcomes. For example, in a study of patients undergoing coronary artery bypass graft (CABG) surgery, researchers randomly assigned participants to either a pre-surgery intervention designed to optimize outcome expectations, an active control intervention focusing on emotional support and advice, or a standard medical care (SMC) condition that proceeded as usual. The patients in the outcome expectations condition showed significantly larger improvements in disability compared to the SMC condition and marginally significant improvements compared to the active control condition (Rief et al., 2017). There is also evidence that temporal expectations can independently shape physiological outcomes. For example, in a study of placebo analgesia, researchers told some participants that the (placebo) analgesic cream takes 5 minutes to start working, some participants that it takes 30 minutes to start working, and some participants that it was simply a cream with hydrating properties; the analgesic effect of the placebo tracked the expected time of onset (Camerone et al., 2021).

In our study, participants were assigned to one of two conditions: a standard healing condition or a fast healing condition. All participants completed an enrollment survey that collected various demographic information and psychosocial variables known to influence physical healing (e.g., perceived stress, anxiety, and mindfulness), as well as a validated self-report measure of visual function (Mangione et al., 1998). We also included a measure of participants' General Healing Expectations ("Compared to other people, my recovery time after an injury is generally…" with three items rated on 6-point bipolar scales: Slower – Faster, Harder – Easier, More Painful – Less Painful), since we assume beliefs about physiological processes influence the way they unfold. Indeed, we designed our experimental intervention with our proposed Embodied Models of Health theoretical framework in mind (Aungle, Matta, Chen, et al., 2026). In that framework, we argue that beliefs are the fundamental drivers of mind-body effects on health, as a result of their influence on attention allocation and expectation formation. Since beliefs and expectations often go hand in hand, we took a two-pronged approach when designing the experiment.

The first prong targeted the beliefs and expectations components of the EMH framework. We created short "pre-operative information" videos that participants were required to watch before each surgery (i.e., they watched the same video twice), in which we filmed their surgeon providing basic recovery information following cataract surgery, including expected timeframes for different symptoms to resolve and for noticeable improvements in vision to occur. The video was followed by 6 multiple choice questions, 3 of which asked specifically about the healing times provided in the video. In the fast healing condition, the expected timeframes were all shifted to the left (e.g., both sets of multiple choice questions asked participants to complete the sentence "Vision often noticeably improves within…," but the correct answer for the fast healing condition was “within 24 hours after surgery, and certainly by 5-7 days following surgery” versus “within 48 hours after surgery, and certainly by 1 week following surgery” for the standard healing condition). The differences in the expected healing times provided in the videos were subtle in order to present minimal risk to study participants, per Harvard’s Institutional Review Board. The purpose of the videos was to influence what participants believed about how long healing would take and to anchor expected healing times to those timeframes.

The second prong targeted attention allocation processes. In addition to the video intervention, participants in both study conditions received a total of 20 “daily check-in surveys,” 10 surveys after each surgery, which were sent between their 1-day and 2-week follow-up visits. For participants in the fast healing condition, the surveys were designed to prompt participants to notice small or subtle changes in their healing symptomology. On the first day of the survey, participants in the fast healing condition were asked questions like, “At the present time, how would you describe your eyesight using both eyes (with glasses or contact lenses, if you wear them)?” and responded on a scale ranging from 1 to 10, with “1 = worst possible eyesight, 5 = some blurriness but okay, 10 = best possible eyesight.” From days 2 to 10, the questions were all changed slightly by adding “compared to yesterday” to the beginning. For example, “Compared to yesterday, how would you describe your eyesight using both eyes (with glasses or contact lenses, if you wear them)?” with the scale “1 = much better eyesight than yesterday, 5 = about the same as yesterday, 10 = much worse eyesight than yesterday.” This survey design was meant to nudge participants to notice small changes in their recovery, since we believe attending to subtle changes in physiology shapes how physiological processes unfold, analogous to paying attention to the breath and in so doing changing how the respiratory process unfolds (Aungle, Matta, Loecher, et al., 2026). In previous work, Langer has argued that attending to symptom variability is the key to understanding the placebo effect (Langer, 2023; Francesco Pagnini et al., 2015; Zilcha-Mano & Langer, 2016), which is especially relevant to chronic health conditions in which people assume their symptoms are stable or are inevitably worsening (e.g., Leventhal et al., 2016). In our Embodied Models of Health framework (Aungle, Matta, Chen, et al., 2026), we argue that attention is a belief-weighted mediator between mind and body. Within that framework, the pre-operative information videos were intended to shape how quickly participants believed and expected healing to unfold, while the daily check-in surveys were intended to amplify healing physiology consistent with participants’ expectations. Assuming participants in the fast healing condition internalized the provided expected healing times, noticing variability in healing consistent with those expectations should facilitate actual healing.

For participants in the standard healing condition, the daily check-in surveys were designed to match the length and duration of the surveys completed by participants in the fast healing condition, but the questions were more open-ended and asked primarily about how participants were feeling (i.e., attention was not directed to the physiology of healing). Survey items included questions like, “How have you been feeling today? We are interested in the levels of stress, anxiety, and pain you have been experiencing,” which was asked as a free response question. We included some likert items as well, such as “Below are a number of statements that refer to your personal outlook. Please indicate the extent to which you agree with each of these statements.” The specific items included statements like, “I am feeling happy right now” and “I am feeling stressed right now,” which participants rated on a scale ranging from 1 = strongly disagree to 6 = strongly agree. We used an active control group design in order to provide a more conservative test of our hypothesis.

Lastly, participants completed a final study survey three months after their first surgery, which was essentially the same as the enrollment survey. The main reason we included this survey was to assess changes in self-reported visual function, using the NEI-VFQ 25, from baseline to three months after surgery.

In parallel with, but separate from, our experimental procedures, we worked with our collaborating medical team to collect objective measures of visual acuity as well as to record any complications as a result of either surgery. Visual acuity measures were obtained at baseline (prior to surgery), 1 day after each surgery, 1 to 2 weeks after each surgery, and 3 months after the second surgery. These objective clinical measures of visual acuity served as our primary dependent variables, with the difference between baseline visual acuity and 1-day and 1-to-2 week post-surgery visual acuity serving as our measures of healing. The difference between baseline visual acuity and 3-month post-surgery visual acuity, as well as the difference between baseline and 3-month post-surgery self-report visual function, served as our measures of overall outcomes, allowing us to test whether our fast healing intervention not only increased the rate of healing but also led to better outcomes overall.

Our experimental intervention was ultimately quite minimal. Participants in the fast healing condition could easily come across the standard healing timeframes given for cataract surgery online, if they sought them, undermining the information we provided in our videos. Additionally, participants could perfunctorily complete the check-in surveys, reducing the influence of attention on the healing process. Any improvement in the fast healing condition relative to the standard healing condition would thus be strong evidence that psychology shapes the physiology of healing.

Study Procedure

141 participants (average age = 71.5 years old, SD = 7.2 years; 86 women; 94.3% White, 3.5% Asian, 0.7% Black or African American, 1.4% Other) were recruited from two ophthalmology clinics in Vermont and Boston for a study on "psychological influences on recovery following cataract surgery." All participants saw the same surgeon. Participation lasted approximately three months from the date of the first surgery. In order to participate, patients had to be cleared by their surgeon. Eligibility criteria included patients undergoing bilateral cataract surgery without rare complications or exceptionally severe cases. Patients with significant pre-existing, vision-limiting retinal or corneal pathologies were excluded. After clearance, we obtained informed consent via an enrollment survey that, in addition to demographic information, collected measures of chronic stress using the Perceived Stress Scale (Cohen et al., 1983), anxiety using the Hospital Anxiety and Depression Scale (Zigmond & Snaith, 1983), mindfulness using the Langer Mindfulness Scale (Pirson et al., 2012), and self-reported visual function using the National Eye Institute's Visual Function Questionnaire (Mangione et al., 1998). We measured the Big Five personality traits using the Ten-Item Personality Inventory (Gosling et al., 2003), following the protocol of Aungle and Langer (2023), in order to maintain our cover story, which was, "we are interested in the relationship between psychological factors and recovery following cataract surgery." After enrollment, participants were randomly assigned to one of two study conditions: fast healing or standard healing. The medical team was blind to which participants were in which condition.

Fast healing condition

Participants in the fast healing condition received an intervention designed to accelerate their recovery from cataract surgery. We employed the following procedure.

1. Eligible patients were given information about the study from their ophthalmologist. If they were interested in participating, their contact information was provided to the study team.

2. The study team sent a brief introductory email and provided a link to an enrollment survey.

3. By completing the enrollment survey, patients also provided informed consent and became study participants.

4. One day prior to their first surgery, the study team sent a link to a short "pre-operative information video" for participants to watch before their surgery. If needed, a study team member called participants to remind them to watch the video. Participants who watched the video were compensated with $5 Amazon Gift Cards.

5. One day after their surgery, they returned to their ophthalmologist's office for a follow-up visit that included a clinical visual acuity exam.

6. Two days after their surgery, participants started to receive "daily check-in surveys." As previously mentioned, the surveys for participants in the fast healing condition were designed to encourage them to notice subtle changes in their symptomology and vision from day to day. So long as their second surgery was at least two weeks after their first surgery, participants were sent a total of 10 daily check-in surveys before their second surgery. In cases where their second surgery was within less than 2 weeks of their first surgery, participants received check-in surveys that began 48 hours after their first surgery and ended 48 hours before their second surgery. Participants received $5 Amazon Gift Cards for completing this round of check-in surveys.

7. Two weeks after their first surgery, participants returned to their ophthalmologist's office for follow-up visits that included clinical visual acuity exams. For participants who received their second surgeries within less than two weeks of their first surgeries, this follow-up exam occurred on the date of their second surgery, before the surgery was performed.

8. One day prior to their second surgery, the study team sent a link to the same "pre-operative information video" that participants watched before their first surgery. Participants who watched the video were compensated with $5 Amazon Gift Cards.

9. One day after their second surgery, participants returned to their ophthalmologist's office for follow-up visits that included clinical visual acuity exams.

10. Two days after their surgery, we repeated the process described in step 6. Participants who completed this round of check-in surveys again received $5 Amazon Gift Cards.

11. Two weeks after their second surgery, participants returned to their ophthalmologist's office for follow-up visits that included clinical visual acuity exams.

12. Three months after their first surgery, participants received a final study survey that included a validated self-report measure of visual function, the NEI-VFQ 25, which was used to assess changes from the baseline scores we collected during enrollment. Participants received $5 Amazon Gift Cards for completing the final study survey.

13. Three months after their second surgery, participants returned to their ophthalmologist's office for their last follow-up visit, which included a clinical visual acuity exam.

Standard healing condition

The standard healing condition was designed to serve as an active control group, so the procedure for participants in this condition mirrored the procedure used for participants in the fast healing condition. The only things that differed were the healing times given in the pre-operative information video and the questions asked in the daily check-in surveys. The healing times provided in the pre-operative information video were all the standard timeframes ophthalmologists typically provide to cataract surgery patients, and the questions in the check-in surveys asked primarily about how participants were feeling and what they had been doing – in contrast to the check-in surveys for the fast healing condition, which prompted participants to notice subtle changes in their healing process. Figure 1 provides a visualization of the study procedure.

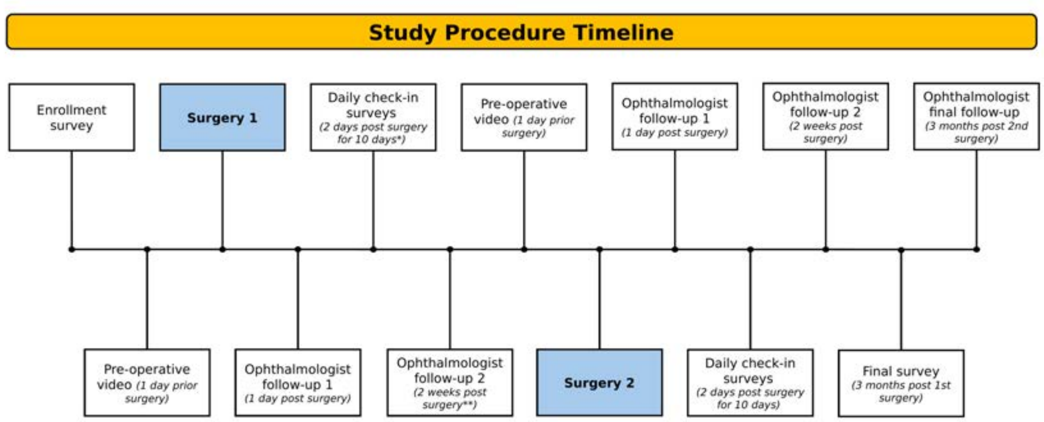

*Figure 1: Study Procedure Timeline. Both the treatment and control groups went through the same study procedure. The only aspects that differed were the healing times given in the pre-operative information video and the questions asked in the daily check-in surveys. *In cases where participants' second surgery was within less than 2 weeks of their first surgery, they received check-in surveys that began 48 hours after their first surgery and ended 48 hours before their second surgery and ** their follow-up exam occurred on the date of their second surgery (before the surgery was performed).*

Compensation

Participants received a total of $25 in Amazon Gift Cards for completing all parts of the study: they received $5 Amazon Gift Cards for watching the pre-operative information videos and answering related questions (x2 = $10 total), $5 Amazon Gift Cards for completing 10 daily check-in surveys following each surgery (x2 = $10 total), and a $5 Amazon Gift Card for completing the final study survey three months after their first surgery and prior to their last follow-up visit at the clinic.

Hypotheses

Our primary hypothesis is that participants in the fast healing condition will show greater improvement in visual acuity (i.e., larger decreases in logMAR from baseline) during the 1-day and 1-to-2-week postoperative visual acuity exams compared to participants in the standard healing condition. Because visual acuity is measured at multiple post-operative time points — 1 day, 1–2 weeks, and 3 months after surgery — we use seemingly unrelated regression (SUR) models to jointly test this hypothesis across waves, allowing us to evaluate whether the intervention effect is jointly significant across the recovery period while accounting for the correlated structure of repeated observations on the same patients. Given our focus on healing, we center our models on visual acuity at the 1-day and 1–2-week time points. We use the 3-month data to assess effects on overall outcomes, once fully healed.

We have two hypotheses motivated by our Embodied Models of Health (EMH) framework:

1. **Attention-to-healing hypothesis.** Among participants in the fast healing condition, daily attention to variability in the healing process (as measured by the average daily check-in survey scores) will predict larger improvements in visual acuity, even after controlling for age and baseline psychosocial variables (perceived stress, mindfulness, and anxiety). We test this using SUR to jointly evaluate the attention coefficient across post-operative waves.
2. **Sensitivity moderation hypothesis.** The effect of attention to healing on visual acuity recovery will be moderated by participants' sensitivity to the healing-time information provided in the pre-operative video, operationalized as the mean number of healing-time questions answered correctly. We predict a significant Attention × Sensitivity interaction, such that the relationship between attention and healing will be strongest among participants who internalized the expected healing times conveyed in the video.

Results

Objective visual acuity was assessed at baseline and at each post-operative follow-up visit using standard clinical visual acuity exams. Visual acuity values were converted to *logarithm of the minimum angle of resolution* (logMAR) units prior to analysis. logMAR provides an approximately interval-scaled measure of visual acuity in which equal changes reflect equal proportional changes in visual resolution, making it well suited for modeling change over time (e.g., Holladay, 1997). Rate of healing was operationalized as the change in logMAR visual acuity from baseline to one-day and one-to-two-week post-surgery visual acuity, while overall surgical outcomes were operationalized as the change from baseline to the 3-month follow-up visit. Negative change scores indicate greater improvement in visual acuity.

Just as we did in our study of perceived time and physical healing (Aungle & Langer, 2023), we measured several psychosocial variables known to influence physical healing: chronic stress using the Perceived Stress Scale (Cohen et al., 1983), anxiety using the Hospital Anxiety and Depression Scale (Zigmond & Snaith, 1983), and mindfulness using the Langer Mindfulness scale (Pirson et al., 2012). We also included a measure of participants' General Healing Expectations (i.e., the extent to which they believe they heal faster than other people), since we have argued beliefs about how physiological processes unfold shape how they actually unfold (Aungle, Matta, Chen, et al., 2026).

Analytical Framework

Whether the video intervention and attention to healing predicts recovery at any single time point is less central to our reasoning than whether these effects are jointly significant across the recovery period. Our data have a natural multivariate structure: the same participants contribute visual acuity outcomes at multiple post-operative time points. To address this, we use seemingly unrelated regression (SUR) as our primary analytic framework. (Note: we often refer to the 1-day postoperative visual acuity exams as wave 1, to the 1-to-2-week postoperative visual acuity exams as wave 2, and to the 3-month postoperative visual acuity exam as wave 3.)

SUR estimates separate regression equations for each wave simultaneously – for example, one equation predicting Wave 1 logMAR change and another predicting Wave 2 logMAR change – using the same set of predictors (daily attention to variability, age, PSS-14, LMS-14, HADS-A). Critically, SUR models the correlation between residuals across equations, reflecting the fact that a patient who heals unexpectedly well at one time point is likely to heal unexpectedly well at another. This cross-equation error correlation allows SUR to produce a joint chi-squared test of whether a given predictor is simultaneously zero across all waves – a principled way to evaluate whether an effect is present across the recovery period while correctly accounting for the non-independence of repeated observations on the same individuals.

When the predictor variables are identical across equations, as they are here, the SUR point estimates for each wave are equivalent to those obtained from wave-by-wave ordinary least squares (OLS). The value of SUR lies not in more efficient individual coefficients, but in the joint test itself. We complement the SUR analyses with pooled OLS, in which we stack observations across waves and estimate a single regression. Pooled OLS yields a single summary coefficient and is useful for interpretation, but it treats all observations as independent, which artificially inflates the effective sample size and can produce overly liberal p-values. The SUR and pooled OLS results are reported together to give a complete picture: the pooled OLS provides a point estimate and confidence interval for the overall effect, while the SUR joint test provides a more conservative and statistically appropriate test of significance. We report results for one-tailed tests, since our prediction is directional (Hales, 2024).

Descriptive results

Figure 2 presents violin plots comparing the distribution of change in visual acuity (logMAR) between the fast healing (treatment) and standard healing (control) groups at each wave, averaged across both eyes. Both groups improved from baseline at every time point, with mean change scores consistently below zero. The treatment group showed slightly larger mean improvements at each wave: at Wave 1, the mean change was −0.096 ($N = 70$) logMAR for the treatment group compared to −0.082 (N = 71) logMAR for the control group; at Wave 2, −0.159 (N = 69) versus −0.140 (N = 69); and at Wave 3, −0.150 (N = 53) versus −0.144 (N = 57). Although these group-level differences are modest, the treatment group's directional advantage was consistent across all three waves. Moreover, these mean-level differences do not account for the two prongs of our intervention: internalizing the faster expected healing times provided in the preoperative video and attending to subtle changes in healing throughout the recovery process.

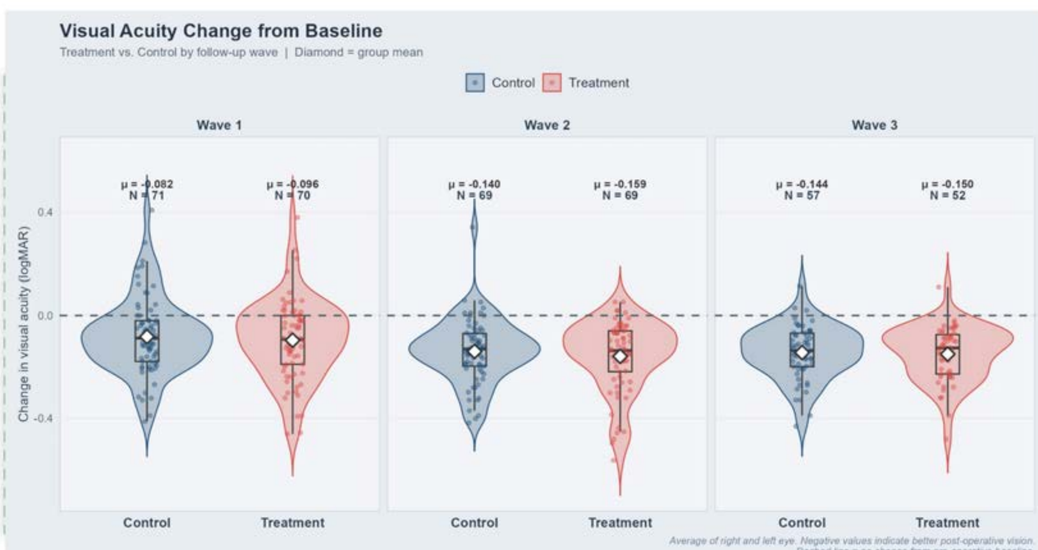

Figure 2. Visual acuity change from baseline. Violin plots comparing the distribution of change in visual acuity (logMAR) between the treatment and control groups at each postoperative wave. Diamond = group mean. Negative values indicate better post-operative vision. Dashed line = no change from pre-operative baseline.

Hypothesis testing

Hypothesis 1

To test our first hypothesis, for participants in the treatment group, we calculated a single *daily attention to variance* score using their responses to the daily check-in surveys. The check-in surveys included 6 questions that asked about the changes participants noticed in their healing process compared to the previous day, rated on 10-point scales. If participants did not notice any changes from the previous day, they were instructed to select 5 on the scale. For five of the six questions, if participants chose a number less than 5, that indicated they noticed improvement. If participants chose a number greater than 5, that indicated they noticed worsening. For the sixth question, we asked participants, "Compared to yesterday, how frequently are you spending a few minutes intentionally paying attention to small changes in your vision, for example small changes in blurriness, ability to read from slightly greater distances, or fewer unpleasant sensations in and around your eyes?" Participants were instructed to select 5 if their behavior was about the same as the previous day, a number greater than 5 if they spent more time, and a number less than 5 if they spent less time.

We took the difference between 5 and the selected rating, such that positive values indicate participants noticed improvement, and negative values indicate participants noticed worsening.

We averaged these values for all six questions across all of the daily check-in surveys to calculate a single measure. The daily attention variable is thus a composite measure of participants' attention to variance throughout the recovery period. For participants in the control group, whose daily check-in surveys only asked about what they were doing and how they were feeling, we assigned daily attention scores of zero.

Figure 3 plots the relationship between daily attention to healing and visual acuity recovery at each wave, with the solid purple line showing the treatment group slope and the short gray line indicating the control group mean. The regressions are adjusted for age, PSS-14, LMS-14, and HADS-A at enrollment. At Wave 1, the slope of attention to healing on change in visual acuity was −0.0266 (p_1 = 0.114, ns); at Wave 2, the slope was −0.0388 (p_1 = 0.021). The negative slopes at Waves 1 and 2 indicate that greater daily attention to healing variability was associated with larger improvements in visual acuity (i.e., more negative logMAR change scores), consistent with our prediction. The effect was strongest at Wave 2, which corresponds to the 1–2 week follow-up visits – the time point at which the cumulative influence of daily attention would be expected to be most apparent.

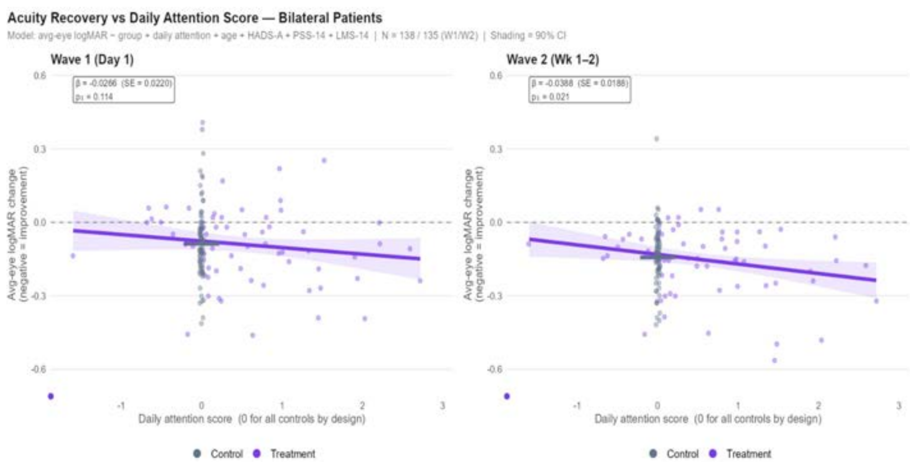

Figure 3. Acuity recovery vs. daily attention score. Scatter plots showing the relationship between daily attention to healing variability and visual acuity recovery at Wave 1 (Day 1) and Wave 2 (Wk 1–2). Lines show model-predicted values at covariate means. Controls cluster at x = 0 (no daily survey variation by design). Shading = 90% CI. p-values one-tailed.

Using Wave 1 and Wave 2 data, the SUR and pooled OLS models show positive associations between attention to healing and actual healing outcomes, controlling for participant age and psychosocial variables (perceived stress, mindfulness, and anxiety). As shown in Figure 4, the pooled OLS estimate of the attention-to-healing coefficient across Waves 1 and 2 was −0.0327 logMAR (SE = 0.0144; p_1 = 0.012), indicating that a one-unit increase in the daily attention-to-healing composite was associated with an additional 0.0327 logMAR improvement in visual acuity. To put this effect size in intuitive terms, a change of 0.1 logMAR is equivalent to being able to see one additional line on a Snellen eye chart, so each one unit increase in attention to healing is equivalent to being able to see about one third of an additional line. The individual regressions at wave 1 and wave 2 were both in the predicted direction using one-tailed tests, but the SUR joint test across the two waves did not quite reach significance ($\chi^2(2)$ = 4.25, p_1 =

0.060), indicating that while the pattern of effects was consistent with our prediction, the evidence for a joint effect of attention across both waves was suggestive rather than definitive. Together, these results suggest that among participants in the fast healing condition, those who attended more closely to variability in their healing process experienced meaningfully larger improvements in visual acuity during the recovery period. Although the joint test of significance did not meet the .05 threshold, attention to variability was associated with healing in the manner the Embodied Models of Health framework would predict, and attention is only one component of that model. The beliefs and expectations component needs to be included to evaluate the EMH predictions more fully.

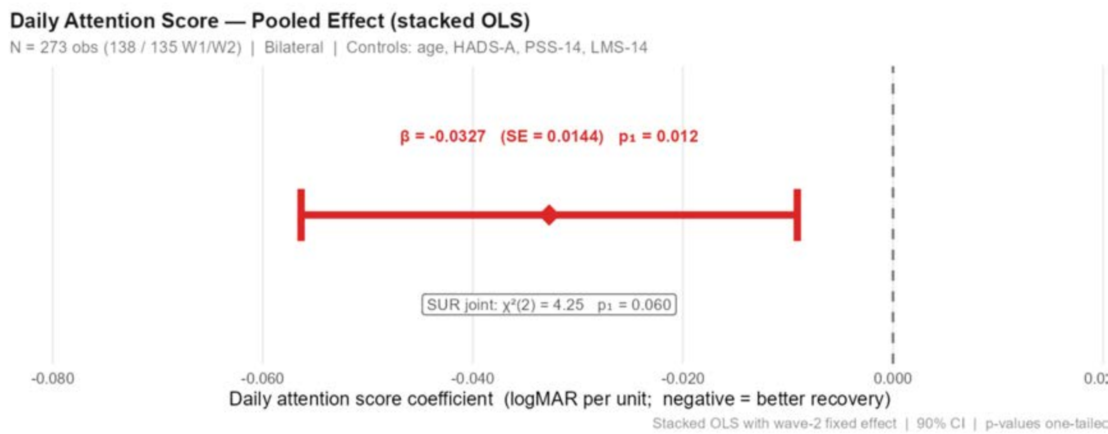

Figure 4. Daily attention score — pooled effect. Pooled OLS coefficient estimate with 90% CI (one-tailed). Stacked OLS with wave-2 fixed effect. N = 273 obs (138/135 W1/W2). Controls: age, HADS-A, PSS-14, LMS-14.

Table 1. Daily Attention Score — Full Specification (Wave 1, Wave 2, Pooled)

Dependent variable: average pooled logMAR change

	Wave 1 (Day 1)	Wave 2 (Wk 1–2)	Pooled
	(1)	(2)	(3)
Treatment group	0.011	0.012	0.012
	(0.028)	(0.024)	(0.018)
Daily Attention Score	−0.027	-0.039^{**}	-0.033^{**}
	(0.022)	(0.019)	(0.014)
Age	0.006^{***}	0.004^{**}	0.005^{***}
	(0.002)	(0.002)	(0.001)
Anxiety (HADS-A)	−0.031	−0.033	-0.032^{*}
	(0.034)	(0.030)	(0.022)
Stress (PSS-14)	0.019	0.026	0.022
	(0.031)	(0.027)	(0.020)

	Wave 1 (Day 1)	Wave 2 (Wk 1–2)	Pooled
Mindfulness (LMS-14)	−0.004	0.001	−0.001
	(0.018)	(0.015)	(0.012)
Wave 2 (FE)			-0.059^{***}
			(0.017)
Constant	-0.095^{***}	-0.154^{***}	-0.095^{***}
	(0.019)	(0.016)	(0.015)
Observations	138	135	273
R^2	0.099	0.098	0.133
Adjusted R^2	0.058	0.056	0.110

Note: *** p < .01, ** p < .05, * p < .10 (one-tailed). SE in parentheses. All covariates mean-centered. Bilateral patients only. Daily Attention Score = 0 for controls by design. Pooled: stacked OLS with wave fixed effect; N = stacked row count. SUR joint test (W1+W2): $\chi^2(2) = 4.25$, $p_1 = 0.060$.

Hypothesis 2

To test our second hypothesis, we examined whether the effect of daily attention to healing on visual acuity recovery was moderated by participants' sensitivity to the healing-time information provided in the preoperative video. As described in the Hypotheses section, sensitivity was operationalized as the mean number of healing-time questions answered correctly in the survey that followed each preoperative video viewing. Participants who answered more of these questions correctly are assumed to have more fully internalized the expected healing times conveyed in the video, which, according to our Embodied Models of Health framework, should amplify the effect of attending to healing variability.

We included an Attention × Sensitivity interaction term in our SUR and pooled OLS models, controlling for age, PSS-14, LMS-14, and HADS-A at enrollment. The results strongly supported our prediction. As shown in the left panel of Figure 5, the pooled OLS estimate of the Attention × Sensitivity interaction coefficient (with psychosocial controls) was negative and fell almost entirely below zero, indicating that participants who both attended to healing variability and internalized the video's healing times experienced larger improvements in visual acuity. The SUR joint test across waves 1 and 2 was clinically meaningful and marginally significant ($\chi^2(2) = 4.20$, $p_1 = 0.061$), suggesting the interaction effect was jointly present across the recovery period. To put the Attention × Sensitivity coefficient in perspective, the average total improvement from cataract surgery was approximately 0.145 logMAR, so the coefficient of 0.07 logMAR means for each one unit increase in the interaction term, visual acuity improved by nearly half the total surgical improvement, or nearly three quarters of an additional line on a Snellen eye chart.

The right panel of Figure 5 illustrates this interaction by splitting the treatment group at the median sensitivity score (range = 0 to 3, median = 1.5). Among high-sensitivity participants (those who answered at least two of the three healing-time questions correctly; n = 36), the relationship between daily attention to healing and visual acuity improvement was negative and statistically significant (slope = −0.048, $p_1 = 0.016$): the more they attended to variability in their healing process, the more their vision improved. Among low-sensitivity participants (those who answered fewer than two questions correctly; n = 28), there was no such relationship (slope = +0.019, $p_1 = 0.305$). In other words, attending to healing variability only predicted faster recovery for participants who had internalized the faster healing times conveyed in the preoperative video. This pattern is consistent with our theoretical framework, which predicts that attention to physiological processes amplifies healing in a direction consistent with one's expectations. Participants who internalized the expectation of faster healing and then noticed day-to-day changes consistent with that expectation healed more than those who did not. Importantly, simply attending to variability alone did not have any consistent effect: low sensitivity participants, if anything, seemed to experience worse outcomes the more they claimed to notice improvement.

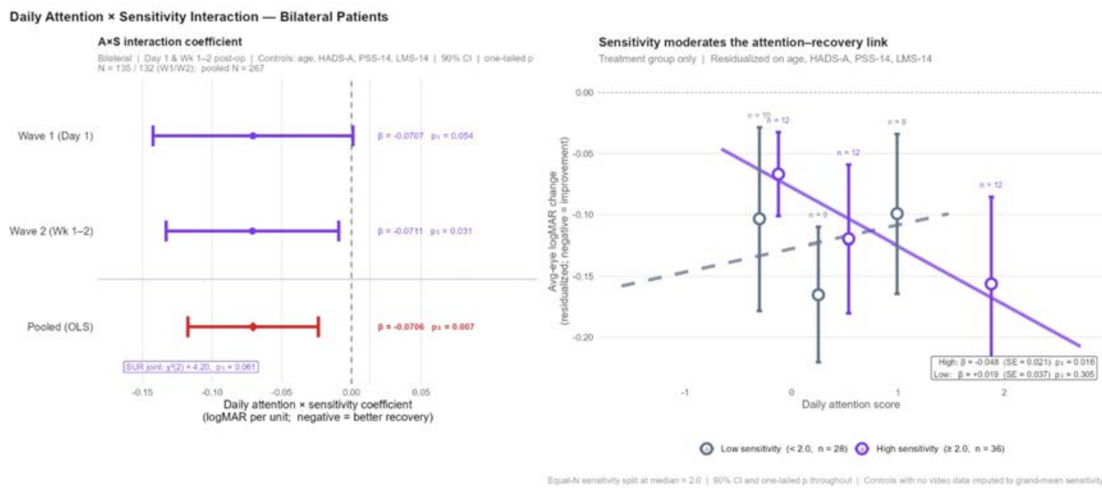

Figure 5. Daily Attention × Sensitivity interaction. Left panel: A×S interaction coefficient at each wave and pooled, with 90% CI (one-tailed). Right panel: residualized scatter plot split at median sensitivity (≥ 2.0, n = 36 high; < 2.0, n = 28 low). Controls with no video data imputed to grand-mean sensitivity.

Table 2. A×S Interaction — Full Specification (Wave 1, Wave 2, Pooled)

Dependent variable: average pooled logMAR change

	Wave 1 (Day 1)	Wave 2 (Wk 1–2)	Pooled
	(1)	(2)	(3)
Treatment group	0.030	0.034	0.032^{*}
	(0.031)	(0.027)	(0.020)
Sensitivity (S)	0.038^{*}	0.010	0.024^{*}
	(0.028)	(0.025)	(0.018)
Treatment × Sensitivity	−0.028	0.034	0.002
	(0.043)	(0.038)	(0.029)
Daily Attention Score (A)	-0.033^{*}	-0.049^{***}	-0.041^{***}
	(0.023)	(0.020)	(0.015)
Attention × Sensitivity (A×S)	-0.071^{*}	-0.071^{**}	-0.071^{***}

	Wave 1 (Day 1)	Wave 2 (Wk 1–2)	Pooled
	(0.044)	(0.038)	(0.028)
Age	0.006***	0.004**	0.005***
	(0.002)	(0.002)	(0.001)
Anxiety (HADS-A)	−0.048*	−0.046*	−0.047**
	(0.035)	(0.031)	(0.023)
Stress (PSS-14)	0.027	0.032	0.029*
	(0.031)	(0.028)	(0.021)
Mindfulness (LMS-14)	−0.007	−0.001	−0.004
	(0.018)	(0.015)	(0.012)
Wave 2 (FE)			−0.058***
			(0.017)
Constant	−0.110***	−0.163***	−0.108***
	(0.020)	(0.017)	(0.015)
Observations	135	132	267
R^2	0.150	0.142	0.173
Adjusted R^2	0.088	0.078	0.141

Note: *** $p < .01$, ** $p < .05$, * $p < .10$ (one-tailed). SE in parentheses. All continuous covariates mean-centred. Bilateral patients only. Key coefficient: A×S. Pooled: stacked OLS with wave FE; N = stacked rows. SUR joint test (W1+W2): $\chi^2(2) = 4.20$, $p_1 = 0.061$.

Additional Analyses

Our medical team collaborators cautioned us at the outset that even if our intervention accelerates healing, we should not expect much of a difference in outcomes (since most patients end up with 20/20 vision once fully healed). Nonetheless, we collected outcome measures of visual acuity out of curiosity. We thought there was a reasonable chance the intervention would generalize beyond healing to overall outcomes. The change from baseline to 3-month postoperative visual acuity and from NEI-VFQ scores at enrollment to NEI-VFQ scores 3 months after surgery served as our measures of overall outcomes.

Figure 6 presents the results. Panel A shows standardized OLS coefficients for the Attention × General Healing Expectations interaction on two outcome measures: change in visual acuity from baseline to 3 months (N=108) and change in vision-related quality of life as measured by the NEI-VFQ (N=119). For visual acuity change at 3 months, the standardized interaction coefficient was negative (indicating greater improvement) but did not reach significance (p_1=0.162). For vision-related quality of life, the interaction coefficient was positive (indicating greater improvement) but did not quite reach significance (p_1=0.077). Panels B and C illustrate these interactions by splitting the treatment group at the median General Healing Expectations score. Among high-GHE participants, greater daily attention to healing was associated with larger improvements in both visual acuity (slope = −0.021, p_1=0.216) and vision-related quality of life (slope = 4.912, p_1=0.018). Among low-GHE participants, attention to healing showed no meaningful relationship with either outcome.

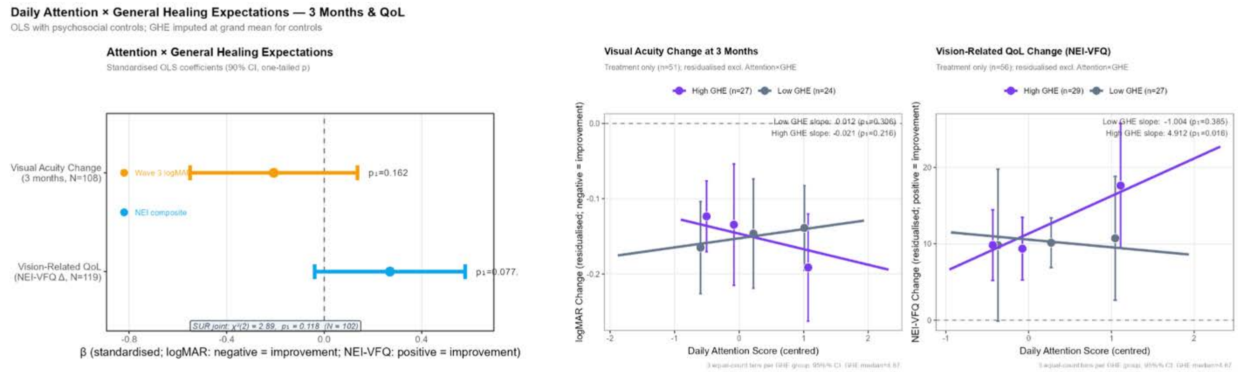

Figure 6. Attention × General Healing Expectations interaction on long-term outcomes (3 months). Panel A: standardized OLS coefficients (90% CI, one-tailed p). Panels B and C: residualized scatter plots split by GHE median (raw = 4.67), treatment group only.

Even with one-tailed tests the results do not quite meet standard definitions of significance, so we are not reporting these as conclusive outcomes. Nonetheless, they are directionally consistent with our framework and, for that reason, interesting. It seems plausible that if our intervention had targeted outcomes as well – instead of being solely and explicitly focused on healing – we might have seen more of an effect. This pattern suggests the intervention did generalize to some extent, which, from a theoretical perspective, makes sense: cultivating constructive beliefs and attending to variability consistent with those beliefs is a more general process. We hope these data offer interesting previews of future research.

Finally, we wanted to assess the robustness of the attention × sensitivity interaction reported here. We created the same model reported for hypothesis 2, except rather than using the sensitivity variable, we used the General Healing Expectations measure we collected during enrollment. We measured General Healing Expectations in Aungle and Langer (2023) as well and found a similar beliefs × attention interaction effect on healing (Aungle, Matta, Loecher, et al., 2026). When we replaced Sensitivity with General Healing Expectations, the results almost perfectly parallel those for hypothesis 2.

Figure 7 presents the results. Panel A shows the OLS coefficients for the Attention × General Healing Expectations interaction on visual acuity change at each wave, as well as the pooled estimate. The interaction coefficient was significant at both Wave 1 (p_1=0.010) and Wave 2 (p_1=0.012), and highly significant in the pooled model (p_1<0.001). The SUR joint test across Waves 1 and 2 confirmed joint significance ($\chi^2(2) = 6.30$, $p_1 = 0.021$, N = 135 patients). Panel B illustrates this interaction by splitting the treatment group at the median General Healing Expectations score (raw = 4.67). Among high-GHE participants (n=36), greater daily attention to healing strongly predicted larger improvements in visual acuity (slope = −0.055, p_1<0.001). Among low-GHE participants (n=31), the relationship was essentially flat and non-significant (slope = 0.016, p_1=0.234). This pattern closely parallels the Attention × Sensitivity interaction reported for Hypothesis 2, with a somewhat stronger effect: the SUR joint test was more clearly significant here (p_1=0.021) compared to marginally significant for the sensitivity variable

(p_1=0.061), and the high-GHE slope (−0.055) was steeper than the high-sensitivity slope (−0.048).

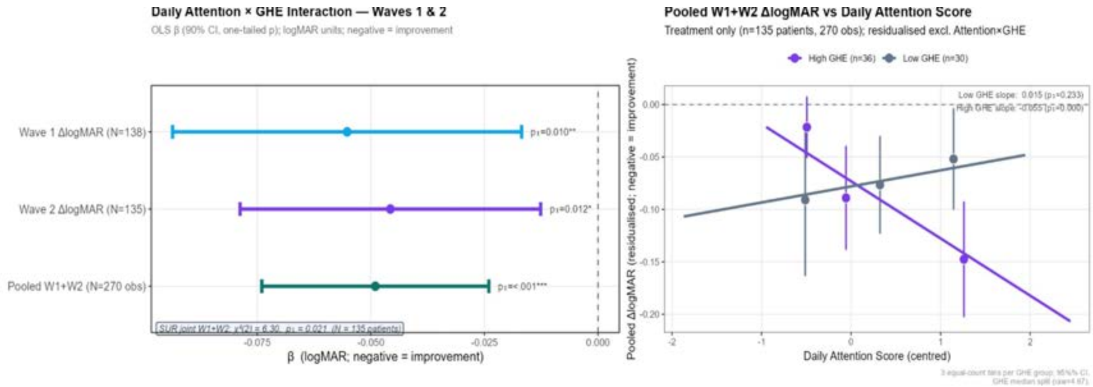

Figure 7. Attention × General Healing Expectations interaction on healing (Wave 1 & Wave 2 logMAR). Panel A: OLS β coefficients (90% CI, one-tailed p) with SUR joint test. Panel B: residualized scatter plot split by GHE median, treatment group only (n=135 patients, 270 observations).

We are thus confident that the belief × attention interaction – so central to the EMH framework – is robust and generalizable. We chose to lead with Sensitivity because that measure is more closely connected to beliefs and expectations in this specific context, rather than beliefs and expectations in general. The fact that both models converge on a nearly identical pattern strongly supports the predictions generated by the EMH framework.

General Discussion

In this study, we sought to extend our perceived time and physical healing findings to recovery following cataract surgery – i.e., from the contrived settings of the laboratory to a real life setting with clear and meaningful implications. More specifically, we tested an intervention designed to accelerate healing after cataract surgery that targeted the pillars of the Embodied Models of Health theoretical framework: we targeted beliefs and expectations with the preoperative video we sent to participants before each surgery, and attention to variability with the daily check-in surveys completed by participants in the fast healing condition. The group-level differences were directionally consistent with our hypothesis (the fast healing group showed larger improvements at every wave) but modest in magnitude. Crucially, however, the more theoretically motivated analyses revealed that the intervention worked through the specific mechanisms the EMH framework predicts: the coefficient of the Attention × Sensitivity interaction was clinically meaningful and marginally significant (SUR joint test $\chi^2(2) = 4.20$, $p_1 = .061$), and when we grouped participants into high sensitivity versus low sensitivity categories, the slope of the regression for high sensitivity participants was significantly different from zero, suggesting that attention to variability only worked for participants who internalized the expected healing times provided in the video – exactly as the EMH framework would predict, since EMH argues attention is a *belief-weighted* mediator between mind and body. Attention weights incoming information according to beliefs; if those beliefs are vague, ambiguous, or conflicting, the ability to systematically weight incoming sensory data is compromised, reducing top-down influences on physiological outcomes.

The relatively modest mean differences between the treatment and active control group overlook the contribution of the interaction, and it is the interaction that captures the prediction of the Embodied Models of Health framework. Indeed, as mentioned in the introduction, the intervention we tested was remarkably minimal (subtle differences in expected healing times, short daily surveys), and participants could easily encounter standard recovery information elsewhere. Nonetheless, the intervention worked as theorized: when participants internalized the faster expectations (high sensitivity) *and* attended to healing variability, they healed significantly more. In other words, participants who engaged with the protocol as intended benefitted as predicted, and the effect among those participants was strong.

The remainder of this discussion proceeds in four parts. First, we unpack the Attention × Sensitivity interaction in terms of the EMH framework proposed in Aungle, Matta, Chen, et al. (2026), arguing that the pattern of results — in which attention to healing variability predicted faster recovery only among participants who internalized the faster expected healing times — provides the first empirical evidence for the claim that attention functions as a belief-weighted mediator between psychological processes and physiological outcomes. Second, we connect the present findings to the perceived time and healing results reported in Aungle and Langer (2023), framing both studies as convergent evidence that temporal expectations shape healing — one tested under tightly controlled laboratory conditions, the other in a real clinical setting. Third, we discuss the clinical implications of these findings for preoperative communication and postoperative care. Finally, we highlight questions that arise from these results and note how they set the stage for future research.

The Attention * Sensitivity Interaction

In Aungle, Matta, Chen, et al. (2026), the authors argue that psychological factors mediate all forms of health, and they provide a framework for thinking about the mechanisms underlying these effects. In their Embodied Models of Health framework, beliefs are the fundamental driver of mind-body effects, but, crucially, this is because beliefs dominate attention allocation and expectation formation. Beliefs about health and performance in general feed through to specific expectations in context. Attention functions as a belief-weighted mediator "between" mind and body, amplifying signals that allow expectations and reality to converge, which is especially relevant to mind-body effects that proceed directly from mental states to physiological outcomes (i.e., effects that are not driven by the role mental states play in shaping behavior and affect). The preceding description is abstract in order to generalize across the varied and complex contexts to which it applies, but we can see how it works in practice by looking at the pattern of results reported here.

When we designed this study, we included multiple choice questions after the preoperative information videos simply to reinforce the information provided in the video; we did not expect many participants to get those answers wrong. It is difficult to know whether and how information is processed and internalized – we do not have direct windows into people's minds – but it was important that the provided healing times were internalized by participants in order for the EMH framework to work. We created the sensitivity variable as a rough proxy for whether participants internalized the provided healing times, which, if anything, the variable likely overstates: some participants may have simply recalled the provided healing times without really believing or internalizing them. Nonetheless, we needed a way to evaluate whether the healing times in the video were believed, and the multiple choice questions allowed us to identify the participants that internalized the expected healing times enough to get the questions right. When we split the sensitivity variable into two groups – high sensitivity (at least 2 of the 3 healing time questions answered correctly) and low sensitivity (fewer than 2 questions answered correctly) – we observed a pattern of results remarkably consistent with what the EMH framework would predict. Among those who internalized the faster healing times (i.e., among high sensitivity participants), greater attention to healing variability significantly predicted larger improvements in visual acuity (slope = −0.048, p_1 = .016).

Among those who did not internalize the faster healing times (i.e., among low sensitivity participants), attention to variability showed no meaningful relationship with healing (slope = +0.019, p_1 = 0.305), and, if anything, trended in the wrong direction. This pattern argues against a simpler interpretation of attention to variability, namely that noticing variability is inherently beneficial. The EMH framework predicts this: attention to variability is neither inherently helpful nor harmful: it's directional. It amplifies signals consistent with whatever model is active. If someone is attending to their healing process without a clear expectation of improvement, what are they attending to? Possibly ambiguity, possibly things that concern them, possibly normal post-surgical discomfort that they interpret as signs of slow or problematic recovery.

The specificity of the Attention × Sensitivity interaction also provides evidence against several alternative explanations for the observed effects. First, the pattern cannot be attributed to demand characteristics since the effect of attention on healing emerged only among participants who had internalized the faster expected healing times. If participants were simply responding to perceived experimenter expectations, we would expect attention to predict healing regardless of sensitivity, which it did not. Second, the results are inconsistent with a simple Hawthorne effect, in which mere participation in a study or increased monitoring drives improvement. We employed an active control group design, in which control group participants were engaged with at the same frequency and for the same duration as treatment group participants. Third, the findings are not reducible to traditional placebo responding. The preoperative video alone, without engaged daily attention, did not produce robust group-level differences between the fast healing and standard healing conditions. It was only when both components were present — when participants believed in faster healing and actively attended to variability consistent with that belief — that the intervention produced meaningfully better outcomes. The necessity of both components, rather than either one in isolation, is precisely what the Embodied Models of Health framework predicts, and it is this specificity that makes the framework's added value clear.

From Perceived Time to Temporal Expectations

In Aungle and Langer (2023), perceived time drove healing: participants who believed more time had passed healed more, even though the elapsed time was always the same. In the introduction of this paper, we argue that effects of perceived time on physiological outcomes occur because perceived time is a key input to expectation formation. The results reported here support this interpretation: rather than manipulating perceived time, which requires false temporal feedback that is impractical to provide outside the lab, we directly manipulated the temporal expectations that perceived time would shape.

In Aungle and Langer (2023), the perceived time manipulation was direct and the context was artificial (precisely calibrated timers, mild bruises produced by cupping). In this study, the manipulation was looser (information in a short video, daily check-in surveys between follow up visits) and the context was real (patients recovering from bilateral cataract surgery). *The fact that effects emerged through the predicted mechanism even under much noisier conditions suggests the underlying principle is robust.*

Taken together, these two studies constitute convergent evidence from very different methodological designs, one laboratory-based and one field-based, pointing to the same conclusion: temporal expectations about physiological processes shape how those processes actually unfold. In the laboratory study, perceived time was directly manipulated with false temporal feedback, and its effect on wound healing was measured under tightly controlled conditions. In the present study, temporal expectations were manipulated indirectly through preoperative information and reinforced through daily attention to healing variability, and their effects were measured in a real clinical population recovering from a common surgical procedure. That both approaches yielded results consistent with the same underlying principle, despite the markedly different levels of experimental control, strengthens the case that the phenomenon is real and generalizable.

Moreover, the present study extends the earlier laboratory findings in an important way by illuminating the role of attention and its interaction with beliefs. In the original laboratory study (Aungle & Langer, 2023), participants were required to monitor a timer and observe their wounds throughout the experimental session, meaning that attention to the healing process was built into the design. Although attention was not independently manipulated in that study, subsequent analyses reported in Aungle, Matta, Loecher, et al. (2026) revealed that the healing observation survey data could be used to calculate an overall measure of attention to variability (ATV). Critically, that ATV measure interacted with a separate measure of participants' general beliefs about how quickly they heal: participants who both believed they heal quickly and attended closely to variability in their wounds healed the most. This interaction between healing beliefs and attention to variability is precisely the joint belief-attention pathway predicted by the EMH framework's computational model (Equation 1 in Aungle, Matta, Loecher, et al., 2026), in which an attention weight modulates the extent to which incoming sensory evidence updates prior beliefs about one's health state.

Because attention was embedded in the laboratory design, however, rather than independently manipulated, the earlier study could not fully disentangle the contributions of temporal beliefs from the contributions of attention. In the present study, attention was explicitly operationalized through the daily check-in surveys, and its interaction with beliefs — captured by the sensitivity variable — was directly tested. The finding that attention to healing variability predicted faster recovery only among participants who had internalized faster expected healing times provides the kind of mechanistic specificity that the earlier laboratory study, by design, could not offer. That both studies converge on the same belief-attention interaction, despite employing very different operationalizations and contexts, strengthens the case that the EMH framework captures a genuine and generalizable mechanism.

Clinical implications

These findings carry several implications for clinical practice. Perhaps the most immediate is that preoperative communication matters more than clinicians may realize. The specific temporal framing of recovery information may actively shape recovery trajectories. This connects to the broader literature on surgical expectations, which has demonstrated that preoperative expectation optimization can improve long-term outcomes (Rief et al., 2017; Auer et al., 2016). Our results add something new to this literature by suggesting that temporal expectations specifically, not just general outcome expectations, play a meaningful role in shaping recovery. The distinction matters because temporal expectations are among the easiest aspects of preoperative communication for clinicians to adjust, and the present findings suggest that even subtle shifts in the timeframes provided to patients could have meaningful downstream physiological consequences.

The daily check-in survey paradigm represents a low-cost, scalable postoperative tool, but it comes with an important caveat. Our results indicate that attention-directing surveys without appropriately calibrated expectations are unlikely to help, and may even be counterproductive. This means that a "one-size-fits-all" recovery monitoring app or check-in protocol is unlikely to produce consistent benefits. What the present results support instead is an integrated approach, one that first sets temporal expectations through preoperative communication and then directs patients' attention to variability consistent with those expectations. As articulated in the EMH framework, the expectation needs consistent sensory evidence that attention can amplify in order for the mechanism to operate effectively. Without the expectation, attention has nothing to anchor to; without attention, the expectation lacks the informational reinforcement needed to sustain its influence on physiology.

It is also worth considering the clinical significance of the observed effect sizes. Among high-sensitivity participants, the slope of daily attention to healing on visual acuity improvement was −0.048 logMAR per unit of the attention composite. In ophthalmological terms, a change of 0.1 logMAR corresponds to one full line on a Snellen eye chart, and clinicians generally consider a change of 0.1 logMAR to be clinically significant. An improvement of 0.048 logMAR is thus approximately equivalent to reading half of the additional letters on the next line down of the chart — a meaningful change, particularly given the minimal nature of the intervention. The entire protocol consisted of a short preoperative information video (under 5 minutes long) and daily check-in surveys that took approximately 2 minutes each to complete. That this low-cost intervention could produce measurable improvements in objective visual acuity among participants who engaged with it as intended suggests a favorable cost-benefit ratio, especially in a surgical context where even small accelerations in recovery can improve patient quality of life and reduce healthcare utilization.

Limitations and Directions for Future Research

Several limitations of the present study point to important directions for future work. First, the sensitivity variable (operationalized as the number of healing-time questions answered correctly after viewing the preoperative video) is an imperfect proxy for belief internalization. Answering a multiple-choice question correctly captures whether participants remembered the information, but it does not directly measure whether they truly believed or internalized it. Some participants may have recalled the correct answer without adopting it as a personal expectation, while others who answered incorrectly may nonetheless have shifted their beliefs. Developing methods that more precisely capture whether a belief has been internalized — and the strength of that belief when activated — would allow for more fine-grained testing of the EMH framework's predictions. Approaches from cognitive science and psychophysics that assess belief strength through behavioral proxies, rather than self-report accuracy, may prove especially useful in this regard.

Second, the daily attention composite is based entirely on self-report. While the check-in surveys were designed to direct and measure attention to healing variability, there remains a meaningful gap between the way attention is conceptualized in the EMH framework, as a precision-modulating process that continuously weights incoming sensory information, and our current ability to measure it in applied settings. Future research should explore methods for measuring attention to bodily processes more directly, potentially through ecological momentary assessment, physiological indicators of interoceptive focus (e.g., fNIRS), or experience-sampling approaches that can capture attentional dynamics in real time.

Third, while the active control group design strengthens our ability to rule out Hawthorne effects, the control group's daily surveys asked about feelings and activities – which does not constitute a pure "no attention" control. Rather, it represents attention directed elsewhere. It remains possible that some control group participants spontaneously attended to their healing physiology, which would attenuate the observed group differences. A stronger test of the attention hypothesis would involve a design in which the control group's attention could be more fully directed away from healing processes.

Fourth, we could not fully control what information participants encountered outside the study. Patients may have searched for recovery information online, spoken with friends or family members who had previously undergone cataract surgery, or received additional guidance from other healthcare providers. Any such exposure to standard recovery timeframes could have undermined the temporal expectations we aimed to establish, particularly for participants in the fast healing condition. Future studies might consider assessing participants' external information exposure as a covariate, or employing study designs that minimize the window for competing information sources.

Finally, the IRB-constrained subtlety of the temporal manipulation, while ethically appropriate, likely attenuated the group-level effect. The differences in expected healing times between conditions were deliberately small in order to present minimal risk to participants. If future studies were able to test more substantial differences in preoperative temporal information — within ethical bounds — the group-level effects might be considerably larger. Alternatively, researchers might explore manipulations that achieve stronger belief shifts through means other than information alone, such as experiential demonstrations or testimonials from prior patients, which may be more effective at establishing internalized expectations.

Conclusion

The central finding of this study is that the physiology of healing following cataract surgery is sensitive to the temporal expectations patients hold and the attention they direct toward the healing process — and, critically, that these two factors interact in precisely the manner predicted by the Embodied Models of Health framework. Neither faster expected healing times alone nor attention to healing variability alone was sufficient to produce robust effects. It was the combination of internalized temporal expectations and engaged attention to variability that predicted meaningfully faster recovery. This interaction is not merely a statistical detail; it is the core prediction of the EMH framework, which holds that attention functions as a belief-weighted mediator between psychological processes and physiological outcomes. The present results provide the first direct empirical test of this prediction in a clinical population.

This finding extends the principle demonstrated in Aungle and Langer (2023) — that temporal perceptions shape the physiology of healing — from the controlled conditions of the laboratory to a real clinical setting. It does so through the theoretical lens developed in Aungle, Matta, Chen, et al. (2026), which provides a mechanistic account of how beliefs, expectations, and attention jointly influence health. In this sense, the present study serves as both a standalone empirical contribution, demonstrating that a minimal psychological intervention can measurably influence surgical recovery, and as the applied arm of a broader theoretical argument about the mechanisms through which psychological factors shape physiological outcomes.

If even subtle shifts in temporal expectations and modest redirection of attention can measurably influence surgical recovery, this raises important questions about the full scope of psychological influences on health outcomes, as well as the adequacy of our language for describing them. The common framing of a "mind-body connection" implies two separate systems that communicate across some interface. But the results reported here do not describe a signal sent from the mind to the body. They describe a process in which the psychological intervention shaped how the body healed. The expectations participants held and the attention they directed did not transmit information to a separate physiological system; they constituted part of the physiological process itself. This is the distinction between mind-body connection and mind-body unity — a distinction that, as we have argued elsewhere (Aungle & Langer, 2023; Aungle, Matta, Chen, et al., 2026), has important implications for how we study, understand, and intervene on health.

The broader implications of mind-body unity for medical science, clinical practice, and public health remain to be fully articulated. What the present findings make clear is that those implications are grounded not in metaphor but in empirical evidence that even minimal psychological interventions can reach deep enough to shape physical healing.

Acknowledgements
This research was supported by funding from Harvard University. The authors have no financial relationships or other potential conflicts of interest to disclose.

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