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Behind the mirror: Factors affecting mirror inspection behaviour in greylag geese

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2. Abstract

Mirror inspection behaviours, such as looking behind a mirror, are commonly interpreted as exploratory or cognitively meaningful responses in animals. However, in species that do not show mirror self-recognition, these behaviours may instead reflect foraging motivation, social assessment, capacity for object permanence, or personality-associated exploration. Here, I tested which factors best explain mirror inspection in free-ranging greylag geese (*Anser anser*), a species that does not exhibit mirror self-recognition. Following a habituation period and across eight treatment days, I presented geese with a wooden board (on which a mirror could be mounted) and a food tray in four conditions: mirror only (mirror with empty food tray), food only (board with full food tray), mirror + food simulated single (mirror with a full food tray pressed up against the mirror, simulating a single larger food source), and mirror + food simulated double (mirror with a full food tray placed 15 cm away, simulating two smaller food sources). For each approach, I recorded whether subjects looked behind the board and quantified the individual repeatability of this response. Looking-behind behaviour occurred almost exclusively during food trials, with significantly higher likelihood in all food conditions relative to the mirror-only control. Differences among the three food treatments were minimal, aside from a modest increase in looking-behind when food was close to the mirror, indicating a small added effect of the mirror stimulus. Looking-behind behaviour was weakly but significantly repeatable among individuals, and younger geese were more likely to exhibit this behaviour. These findings show that geese inspect mirrors primarily when motivated by foraging, with a mirror-mediated effect that may reflect social avoidance, as younger geese preferentially "searched" behind the mirror rather than interact near food. The repeatability of this behaviour suggests that mirror inspection may covary with exploration tendencies or personality-associated information gathering, which remains to be tested.

Keywords: animal personality, *Anser anser*, avian cognition, mirror inspection, mirror test

2.1 Zusammenfassung

Spiegel-Inspektions-Verhaltensweisen, wie das Schauen hinter einen Spiegel, werden häufig als explorative oder kognitiv bedeutsame Reaktionen in Tieren interpretiert. Doch bei Arten, die keine Selbsterkennung im Spiegel zeigen, könnte dieses Verhalten stattdessen die Motivation zur Nahrungssuche, soziale Einschätzung, die Fähigkeit zur Objektpermanenz oder charakterspezifische Exploration widerspiegeln. In dieser Arbeit habe ich untersucht, welche Faktoren das Spiegel-Inspektions-Verhalten von freilebenden Graugänsen (*Anser anser*) am besten erklären können, einer Art, die keine Selbsterkennung im Spiegel aufweist. Nach einer Gewöhnungsphase habe ich über 8 Versuchstage hinweg den Gänsen ein hölzernes Brett (auf dem ein Spiegel montiert werden konnte) und eine Futterschale in vier Kombinationen präsentiert: Spiegel mit leerer Futterschale, Brett mit gefüllter Futterschale ohne Spiegel, gefüllte Futterschale direkt neben dem Spiegel platziert (simulieren eine einzelne, größere Futterquelle), und gefüllte Futterschale 15 cm vom Spiegel entfernt platziert (simulieren zwei kleinere Futterquellen). Bei jeder Annäherung einer Gans an das Brett habe ich aufgezeichnet, ob diese hinter das Brett schaut und die individuelle Reproduzierbarkeit dieses Verhaltens quantifiziert. Das Spiegel-Inspektions-Verhalten kam fast ausschließlich während der Versuche mit Futter vor, mit einer signifikant höheren Wahrscheinlichkeit im Vergleich zu der Nur-Spiegel-Kontrolle ohne Futter. Die Unterschiede zwischen den drei Futter-Versuchen waren minimal, abgesehen von einem leichten Anstieg des Spiegel-Inspektions-Verhaltens, als die Futterschale direkt neben dem Spiegel platziert war. Dies könnte auf einen geringen zusätzlichen Stimulus-Effekt des Spiegels hinweisen. Das Spiegel-Inspektions-Verhalten wies eine geringe, aber signifikante Reproduzierbarkeit innerhalb der Individuen auf, und jüngere Gänse zeigten dieses Verhalten mit einer höheren Wahrscheinlichkeit als ältere Gänse. Diese Ergebnisse zeigen, dass Graugänse vorrangig den Spiegel aus Motivation zur Futtersuche inspizieren. Der Spiegel-Effekt, dass jüngere Gänse es bevorzugten, hinter dem Spiegel nach

dem Futter zu „suchen“, als mit anderen Gänsen darum zu konkurrieren, könnte ein Beweis für soziale Konflikt-Vermeidung sein. Die Reproduzierbarkeit dieses Verhaltens deutet darauf hin, dass die Inspektion des Spiegels mit der Explorationsneigung oder charakterspezifischer Informationserfassung zusammenhängen könnte, was es zukünftig noch zu untersuchen gilt.

Schlagwörter: Tierpersönlichkeit, *Anser anser*, Vogel-Kognition, Spiegel-Inspektion, Spiegel-Experiment

3. Introduction

Natural selection should favour cognitive and perceptual traits that enhance survival and decision-making in complex social and physical environments. Mirror stimulation tests are widely used in behavioural research to measure behaviour and cognition. In these tests, an animal is presented with its reflected image, allowing it to see itself as it is seen by other animals (Gallup Jr, 1968). Depending on the species and context, individuals may respond to mirrors with exploratory, aggressive, anti-conspecific (territorial), or investigative behaviours (Gallup Jr, 1968).

Among the most common uses of mirror-image stimulation is the assessment of mirror self-recognition via the 'mark test' (Medina et al., 2011; Gallup Jr, 1970). In this assay, subjects are marked on their bodies in places that are visible only with the aid of a mirror, and individuals that recognise their own reflection attempt to touch or investigate the marks (Medina et al., 2011). This capacity for mirror self-recognition has been reported in a range of taxa, including chimpanzees (*Pan troglodytes)* (e.g. Gallup Jr, 1970; Povinelli et al., 1993), Asian elephants (*Elephas maximus*) (Plotnik et al., 2006), bottlenose dolphins (*Tursiops truncatus*) (Reiss & Marino, 2001; Morrison & Reiss, 2018), Eurasian magpies (*Pica pica*) (Prior et al., 2008; but see: Soler et al., 2020), Indian house crows (*Corvus splendens*) (Buniyaadi et al., 2020), Clark's nutcrackers (*Nucifraga columbiana*) (Clary & Kelly, 2016), rosy-faced lovebirds (*Agapornis roseicollis*) (Silveira et al., 2023), cleaner wrasse *(Labroides dimidiatus)* (Kobayashi et al., 2024; Kohda et al., 2019; Kohda et al., 2022; but see: de Waal, 2019), and invertebrate species like the Atlantic ghost crab (*Ocypode quadrata*) (Robinson, 2023).

Animals that show mirror self-recognition typically pass through four stages: (1) a social response to their reflection, (2) physical inspection of the mirror, such as looking behind it, (3) repetitive mirror-testing behaviour, and (4) self-directed behaviour, indicating recognition of

the mirror image as themselves (Plotnik et al., 2006). However, most species do not recognise themselves in a mirror and instead remain at stages 1 or 2 (Plotnik et al., 2006), responding to their reflection as though it were an unfamiliar conspecific (e.g. Gallup Jr, 1968, 1970; Kleindorfer, Krupka, et al., 2024; Kleindorfer et al., 2025; Plotnik et al., 2006). Thus, mirror-directed behaviour may emerge from multiple interacting mechanisms rather than mirror self-recognition alone. In species that do not show mirror self-recognition, mirror inspection behaviour – such as looking behind the mirror – may reflect several alternative mechanisms, including foraging motivation, social assessment, object permanence, and exploratory tendencies (Güntürkün et al., 2017; Kleindorfer et al., 2025; Wittek et al., 2021).

An individual's tendency to inspect or explore a mirror could be influenced by a range of factors. Although tufted capuchin monkeys (*Cebus apella*) do not show mirror self-recognition, the frequency and duration of their mirror inspection behaviour depends on their age and tool-using abilities (Westergaard & Suomi, 1995). Siamangs (*Hylobates syndactylus*) (Heschl & Fuchsbichler, 2009), Asian elephants (Plotnik et al., 2006), and magpies (Prior et al., 2008) mainly used mirrors to investigate their own reflection. Conversely, in experiments with pigs (*Sus scrofa*) (Broom et al., 2009; but see: Gieling et al., 2014); dogs (*Canis familiaris*) (Fukuzawa & Hashi, 2017; Howell et al., 2013), and New Caledonian crows (*Corvus moneduloides*) (Medina et al., 2011), the presence of food in addition to a mirror strongly motivated mirror inspection, with subjects often looking behind the mirror or barrier in search of a reflected food item.

In such cases, an individual's tendency to look behind the mirror may be influenced by its comprehension of object permanence (after Piaget, 1954): the understanding that objects continue to exist even when they are temporarily out of the observer's view (e.g. Güntürkün et al., 2017; Piaget, 1954; Zucca et al., 2007). In birds, advanced stages of object permanence have been reported in Eurasian magpies (Pollok et al., 2000), Eurasian jays (*Garrulus glandarius*)

(Zucca et al., 2007), and Goffin's cockatoos (*Cacatua goffini*) (Auersperg et al., 2013). Object permanence is particularly relevant in mirror paradigms because reflected objects appear visually present but physically inaccessible, potentially motivating individuals to inspect behind the mirror or barrier.

Mirror inspection behaviour may also reflect consistent among-individual differences in exploratory behaviour or responses to novelty. Individuals that are more exploratory or less neophobic may be more likely to approach ambiguous stimuli and investigate inaccessible objects (Kleindorfer et al., 2025). This individual consistency in a trait or specific behaviour can be measured by its repeatability (Réale et al., 2007; Boake, 1989). Repeatability is an important index to quantify the accuracy and consistency of phenotypic measurements and represents the proportion of phenotypic variation in a trait that can be assigned to the variation between subjects or between groups (Boake, 1989; Nakagawa & Schielzeth, 2010; Réale et al., 2007). Mirror responses may, therefore, provide insight into not only cognition but also personality-dependent information gathering and behavioural flexibility.

Greylag geese (*Anser anser*) show the first of the four behavioural stages associated with mirror self-recognition, reacting to their reflection as if it were another goose (Kleindorfer, Krupka, et al., 2024; Kleindorfer et al., 2025). A subgroup of these geese also exhibit the second behavioural stage, inspecting the mirror by looking or walking behind it, although the underlying behavioural mechanisms remain unclear (Kleindorfer et al., 2025). This mirror inspection behaviour may reflect foraging motivation, exploratory tendencies, social assessment, or perception of object permanence, yet experimental tests separating these alternative explanations in species that do not show mirror self-recognition remain limited (Güntürkün et al., 2017; Kleindorfer et al., 2025; Wittek et al., 2021). Understanding why some individuals inspect mirrors whereas others do not may, therefore, provide insight into the interaction between social cognition, ecological context, and personality-dependent decision-

making. Notably, in previous experiments with greylag geese, mirrors were always presented together with a food tray (Kleindorfer, Krupka, et al., 2024; Kleindorfer et al., 2025); therefore, it is unclear whether mirror inspection behaviour was a response to the bird's own mirror image, to the reflection of the food tray, or to both.

In this thesis, I investigated the factors influencing mirror inspection behaviour in a free-ranging flock of colour-banded greylag geese. Across eight days, I presented geese with an experimental setup consisting of an upright wooden board and food tray in four conditions: mirror only (mirror mounted on the board with an empty food tray), food only (wooden board only with a full food tray), mirror + food simulated single (mirror and a full food tray placed directly against the mirror, simulating a single larger food source), and mirror + food simulated double (mirror and a full food tray placed 15 cm away from the mirror, simulating two smaller food sources). This experimental design allowed me to test competing explanations for mirror inspection behaviour by separating the effects of food presence, reflected social stimuli, and object permanence, while also assessing whether individuals differed consistently in their tendency to inspect behind the board.

For each approach towards the experimental setup, I recorded whether subjects looked behind the board and quantified the individual repeatability of their response. If food is the main driver for inspection behaviour, I predicted that (1) the likelihood of looking behind would be higher in the three food trials than in the mirror-only control trial, and (2) there would be no differences between the three food trials. If social avoidance behaviour also influences inspection behaviour, I predicted that (3) the likelihood of looking behind would be higher in the two mirror + food trials than in the food-only trial, and higher among younger and less dominant geese. If object permanence affects mirror inspection, I predicted that (4) geese would be more likely to look behind when there are two simulated food trays (mirror + food simulated double) rather than one (mirror + food simulated single). Finally, if mirror inspection behaviour is

associated with a personality trait like exploration, I predicted (5) consistent among-individual differences in the likelihood of looking behind the mirror.

4. Materials and methods

4.1 Study species and study site

I studied a free-ranging flock of greylag geese (*Anser anser*) at the Auingerhof, the former site of the Konrad Lorenz Research Center for Behavior and Cognition (KLF) in Grünau im Almtal, Upper Austria (47°48′49.7412″N, 13°56′51.72″E). The flock was established at this location in 1973 by Konrad Lorenz and colleagues and since then has been continuously monitored by KLF researchers (Hemetsberger et al., 2013). All members of the flock can be individually identified based on their unique combination of aluminium and coloured leg rings (Hemetsberger et al., 2013) or, for the small number of unbanded individuals, based on their facial markings (Kleindorfer, Heger, et al., 2024). Although flock members can freely move, they do not migrate and generally do not leave the Alm Valley (Hemetsberger et al., 2013). Flock members are habituated to human presence because they are fed every morning and afternoon by staff from the KLF (Hemetsberger et al., 2013) and, during the day, by visitors at the nearby Cumberland Wildpark (Katsis et al., 2025). At the time of my experiment, the flock comprised 89 individuals (53 male and 36 female) aged between six months and 20 years (hatch year 2003–2023). Most individuals (53) were in heterosexual or homosocial partnerships at the time of the experiment, with the remaining 36 unpaired.

4.2 Mirror experiments

My study was conducted over 10 days outside of the breeding season (25 September to 4 October 2023) during the geese's morning feeding, between 8:00–9:00am. Because greylag geese are highly neophobic and tend to avoid newly introduced objects in their environment (Kleindorfer et al., 2025), the flock were habituated to the experimental setup for a minimum of two days prior to the first trial (**Fig. 1**). The experimental trials comprised four phases (two

control and two treatment), each lasting for two days and presenting a different trial condition (T0–T3) (**Fig. 1, Fig. 2**).

4.2.1 Behavioural assays

To test which factors influence mirror inspection behaviour, I presented geese with an upright wooden board (~60 × 60 × 8 cm), on which a mirror (~55 × 55 × 4 cm) could be mounted, and a terracotta food tray (31.5 × 16.6 × 3.5 cm). This setup was presented in four conditions: (1) mirror-only control (mirror with empty food tray; T0), (2) food-only control (board with full food tray; T1), (3) mirror + food simulated single (simulating a single larger food source; T2), and (4) mirror + food simulated double (simulating two smaller food sources; T3) (**Fig. 1, Fig. 2**). Trial types T2 and T3 were used to test if social avoidance behaviour influences mirror inspection behaviour, as subjects approaching the feeders would perceive in their reflection an unfamiliar "opponent" approaching either the same or a separate food source (Kleindorfer, Krupka, et al., 2024; Kleindorfer et al., 2025). I placed the boards at four different locations around the feeding area (boards 1–4) (**Fig. S1**). White lime stones from the environment marked the 2-m and 1-m zones in front of each board (**Fig. 3, Fig. S1**).

On the morning of the experiment, geese were fed two 5-L buckets of food (2:1 grass pellets to wheat grains), which were divided between their normal feeding trays in addition to the experimental food trays. On trial days, two of the four boards were fitted with mirrors and/or stocked with food, depending on the trial type, and monitored for one hour. Across days, I alternated which boards were monitored (i.e. boards 2 and 4 on one day, boards 1 and 3 on the next; **Fig. 1**). Halfway through the experiment, the food tray was refilled to encourage more geese to approach (except during the mirror-only control trials). In total, I conducted 16 one-hour trials across the eight trial days of the experiment (i.e. two feeders were recorded simultaneously each day). Trials were recorded using digital video cameras (GoPro Max,

GoPro, Inc., CA 94402, USA) mounted on tripods 4 m from the boards (**Fig. 3**). Geese were free to approach or avoid the boards and multiple geese could be near the feeders at once; hence, not all geese approached the boards on a given day and some geese approached the same board multiple times per day (Kleindorfer, Krupka, et al., 2024). It was not possible to control how many geese were in the surrounding area of the board at any time (Kleindorfer, Krupka, et al., 2024).

4.2.1.1 Mirror-only control

For the mirror-only control trials (T0), the mirror was fitted to the board, with an empty food tray placed 5 cm in front of it (**Fig. 1, Fig. 2**). These trials provided a baseline for testing whether geese are more likely to show mirror inspection behaviour (i.e. look behind the board) when food is present. The importance of food as a motivator for looking behind or exploring an obstacle has previously been shown in pigs (Broom et al., 2009), Eurasian jays (Baciadonna et al., 2023), and New Caledonian crows (Medina et al., 2011).

4.2.1.2 Food-only control

For the food-only control trials (T1), the food tray was positioned 5 cm in front of the board and filled with food, with no mirror visible throughout the experiment (**Fig. 1, Fig. 2**). In this treatment, the food pile was expected to be perceived as the normal size of the food tray. These trials provided a baseline for testing whether geese look behind the mirror to investigate their own mirror image, which is also known from Asian elephants (Plotnik et al., 2006), siamangs (Heschl & Fuchsbichler, 2009), and magpies (Prior et al., 2008).

4.2.1.3 Mirror + food simulated single

In the mirror + food simulated single trials (T2), the mirror was fitted to the board, with the food tray pressed up directly against the mirror. This simulated the presence of a single, larger food source at the board (**Fig. 1, Fig. 2**), perceived as double the size of the food pile in T1.

4.2.1.4 Mirror + food simulated double

In the mirror + food simulated double trials (T3), the mirror was fitted to the board with the food tray placed 15 cm in front, thereby simulating two identical, spatially separated food sources at the board (**Fig. 1, Fig. 2**). These trials were used to test if subjects adjusted their mirror inspection behaviour when expecting to encounter a second food source directly behind the board. Subjects' comprehension of object permanence (after Piaget, 1954) could influence mirror inspection behaviour in this treatment type, allowing them to search for the simulated food source behind the board. The capacity for high stages of object permanence has been demonstrated in other bird species, including magpies (Pollok et al., 2000), Eurasian jays (Zucca et al., 2007), and Goffin's cockatoos (Auersperg et al., 2013).

4.2.2 Behavioural coding

Videos were coded using the software Solomon Coder version beta 19.08.02 (for complete protocols for video coding, see Appendix). Each trial began when an individual goose entered within 2 m of the board and continued for 5 mins, regardless of whether the subject remained within the 2-m zone during that period. During each trial, I recorded the following variables as measures of mirror inspection behaviour: (1) half-looks behind the board, in which the subject looked or moved behind the board and did not return to the front; and (2) full-looks behind the board, where the subject looked or moved behind the board and then returned to the front (**Table S1**). Such behaviours were only recorded if the subject had previously entered the 1-m zone

and directed its head towards the board. Following each 5-min trial, subsequent entries into the 2-m zone by the same individual were scored as independent trials. Trials that began after the 55-min mark were not scored, as the experiment ended before the full 5 mins could elapse.

4.2.3 Calculating dominance rank

I predicted that a goose's dominance ranking might influence how it responded to a perceived 'opponent' reflected in the mirror. The dominance rank of each goose was determined based on 1,511 agonistic interactions observed among flock members in July 2023, as per Kleindorfer, Krupka, et al. (2024). The flock dominance hierarchy was calculated using the randomized Elo-rating method implemented in the R package aniDOM v. 0.1.5 (Farine & Sanchez-Tojar, 2018; Kleindorfer, Krupka, et al., 2024). For temporally stable animal hierarchies like in greylag geese, the function 'elo-scores' was used to multiplicate the input dataset with a randomized order of interactions (1000 replications) to estimate mean individual ranks and 95% confidence intervals (CI) from the calculated Elo-scores (Sánchez-Tójar et al., 2018; Kleindorfer, Krupka, et al., 2024). Individuals that donated an agonistic interaction were defined as winners and individuals that received the agonistic interaction were defined as losers (Kleindorfer, Krupka, et al., 2024).

4.2.4 Statistical analysis

Statistical analysis and visualisation of my data were performed using R version 4.5.1 (R Core Team, 2025). To test my first two predictions, I used a generalized linear mixed model (GLMM) (package 'lme4' version 1.1-37) (Bates et al., 2015) with a binomial distribution. This GLMM included the fixed effects dominance rank, trial type (T0, T1, T2, T3), entry number (the chronological order of the trial per subject and per feeder, range 1–7), sex (male, female), age

(0–20 years), pairing status (paired, unpaired), and the board approached (number 1–4) (**Table S1**), which were factors that potentially influence the response variable look behind (yes, no). Individual ID was included as a random effect to account for the non-independence of repeat trials involving the same individual. To compare the likelihood of mirror inspection among trial types, I conducted ANOVAs using the function *Anova* in the package 'car' (version 3.1-3) (Fox & Weisberg, 2019) and post-hoc pairwise comparisons using the package 'emmeans' (version 1.11.2-8) (Lenth & Piaskowski, 2026), with P-values adjusted for multiple comparisons using the Holm method. To test my third and fourth predictions, I used the same GLMM structure as above but only analysed the two treatment trials where both the mirror and food were present (T2, T3). In addition, because I predicted that lower-ranked geese would be more likely to look behind the mirror during T3 versus T2 trials, I initially included an interaction between dominance rank and trial type in the model. However, this interaction term was not statistically significant and subsequently removed.

Because many geese approached the same feeder multiple times per day, I also checked whether habituation to the boards influenced my results. To do so, I repeated the above analyses using only each goose's first entry per feeder per day. The data from the mirror-only control trials (T0) were excluded from this analysis, because geese never looked behind the board during their first entry in T0.

To test whether individuals differed consistently in their likelihood of looking behind the board (prediction 5), I used the package 'rptR' (version 0.9.22) (Stoffel et al., 2017). The statistical significance of repeatability was tested using likelihood ratio tests against a null hypothesis that $R = 0$, while 95% credible intervals were estimated by parametric bootstrapping (1,000 iterations) (Stoffel et al., 2017). Data were plotted using the package 'ggplot2' version 4.0.0 (Wickham, 2016) and model diagnostics were checked using the package 'DHARMa' version 0.4.7 (Hartig, 2025).

4.3 Animal ethics

This study was conducted under Animal Experiment Licence Number 66.006/0026-WF/V/3b/2014 by the Austrian Federal Ministry for Science and Research (EU Standard) and followed the Austrian laws and regulations concerning the work with wildlife and the 'Guidelines for the use of animals in research' as published in Animal Behavior (1991, 41, 183–186).

5. Results

Over the eight experimental days, I collected mirror inspection data from 1,184 trials involving 87 flock members (**Table S2a–c**). Two additional female geese were excluded from data analysis: one never approached within 2 m of a board during any experiment (Fortuna) and the other had not been assigned a dominance rank (Diega). The following results were calculated using all entries by each goose per feeder and per day.

When analysing all four trial types, the likelihood of mirror inspection behaviour was significantly predicted by trial type ($\chi^2 = 17.58$, df = 3, $P < 0.001$) and board number ($\chi^2 = 14.88$, df = 3, P = 0.002) (**Table 1**). Older geese were less likely to look behind the mirror than younger geese ($\chi^2 = 15.55$, df = 1, $P < 0.001$), while dominance rank, entry number, sex, and pairing status had no effect (**Table 1**).

Post-hoc pairwise comparisons between the four trial types showed that mirror inspection behaviour was more likely in the three food trials (T1–T3) compared to the mirror-only control trial (T0) (**Fig. 4, Table 2**). The three food trials did not differ from each other in their likelihood of mirror inspection, with the exception that looking behind the mirror was more likely in the mirror + food simulated single (T2) trials compared to the food-only control (T1) trials (**Fig. 4, Table 2**).

When analysing only the trials with both food and mirror present (T2 and T3), the likelihood of mirror inspection behaviour was not predicted by trial type ($\chi^2 = 1.62$, df = 1, P = 0.204), indicating that the position of the food tray had no influence (**Table 3**). Mirror inspection was more likely at some boards than others ($\chi^2 = 11.16$, df = 3, P = 0.011; **Table 3**). Once again, older geese were less likely to look behind the mirror than younger geese ($\chi^2 = 10.38$, df = 1, P = 0.001), while dominance rank, entry number, sex, and pairing status had no effect (**Table 3**).

We repeated the above analyses using only each goose's first entry per feeder per day, including only the trials T1–T3. In these analyses, older geese were still less likely to look behind the mirror than younger geese ($\chi^2 = 7.18$, df = 1, P = 0.007), while dominance rank, trial type, sex, pairing status, and board number had no effect (**Table S3**). Post-hoc pairwise comparisons between the three trial types (T1–T3) showed that these trial types did not differ significantly from each other in their likelihood of mirror inspection for the first entries (**Table S4**).

When analysing only the trials with both food and mirror present (T2 and T3, first-entries only), the likelihood of mirror inspection was only predicted by age, with older geese being less likely to look behind the mirror than younger geese ($\chi^2 = 5.49$, df = 1, P = 0.019) (**Table S5**). The factors dominance rank, trial type, sex, pairing status, and board number had no effect on the likelihood of mirror inspection behaviour for the first entries (**Table S5**).

Whether an individual inspected the mirror during the food + mirror trials (T2, T3) was weakly but significantly repeatable (link-scale approximation: R = 0.040, SE = 0.02, 95% CI = 0.00–0.08, P = 0.010), indicating that some individuals were consistently more likely than others to look behind the mirror.

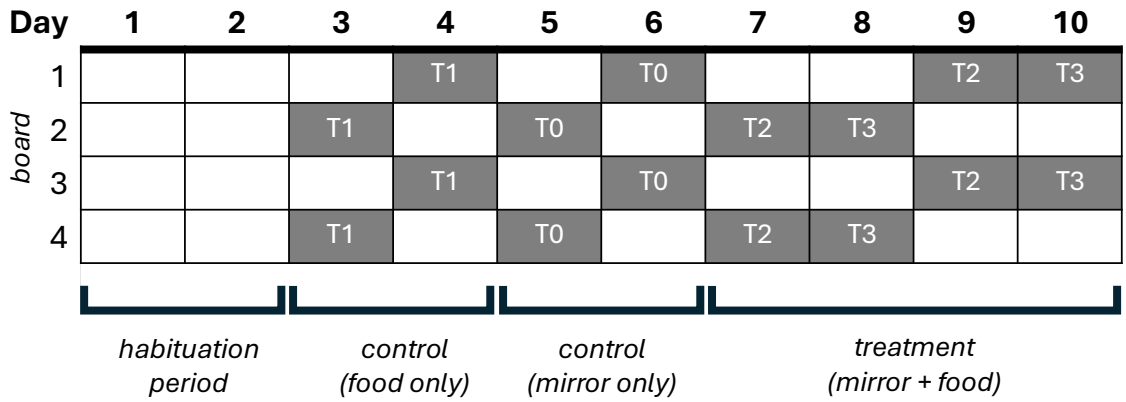

Figure 1. The experimental timeline comprised 10 days: two days of habituation to the feeders (days 1–2) during which no data were collected, four days of control trials (days 3–6), and four days of treatment trials (days 7–10). T0: mirror-only control (mirror with empty food tray); T1: food-only control (board with no mirror and a full food tray); T2: mirror + food simulated single (mirror with a full food tray pressed up against the mirror, simulating a single larger food source); T3: mirror + food simulated double (mirror with a full food tray placed 15 cm away, simulating two smaller food sources). Shaded cells indicate the boards (numbers 1–4) that were monitored on a given day.

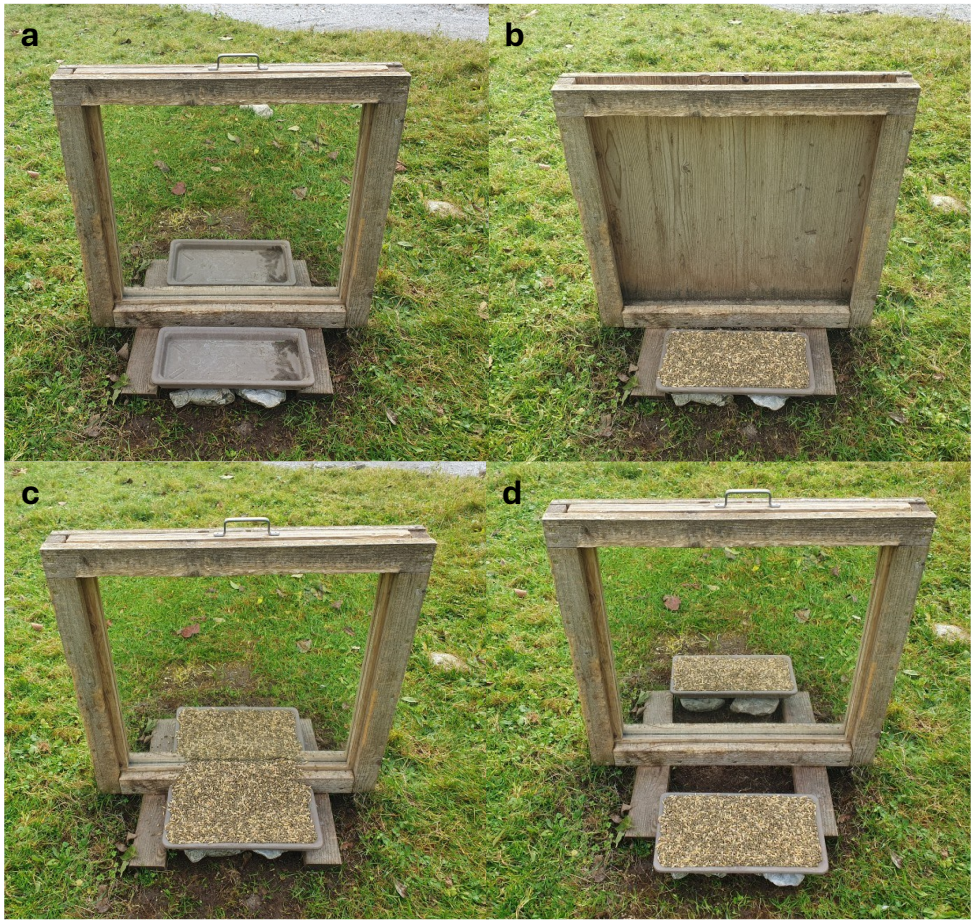

Figure 2. Photos of the experimental setup for the four trial types. (a) T0: mirror-only control (mirror with empty food tray); (b) T1: food-only control (board with full food tray); (c) T2: mirror + food simulated single with the food tray pressed up against the mirror (simulating a single larger food source); (d) T3: mirror + food simulated double with the food tray placed 15 cm away from the mirror (simulating two smaller food sources).

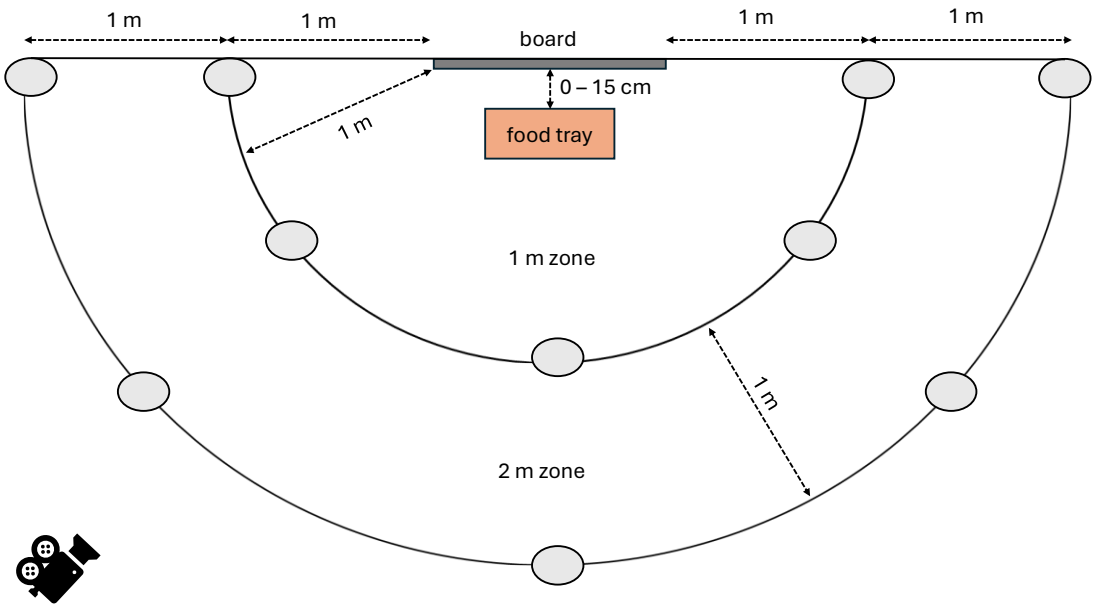

Figure 3. Setup of the mirror experiments. The 2-m and 1-m zones in front of the board were marked with lime stones (grey circles). A tripod-mounted camera was positioned outside the 2-m zone. The food tray was placed 0–15 cm in front of the board, depending on the trial type.

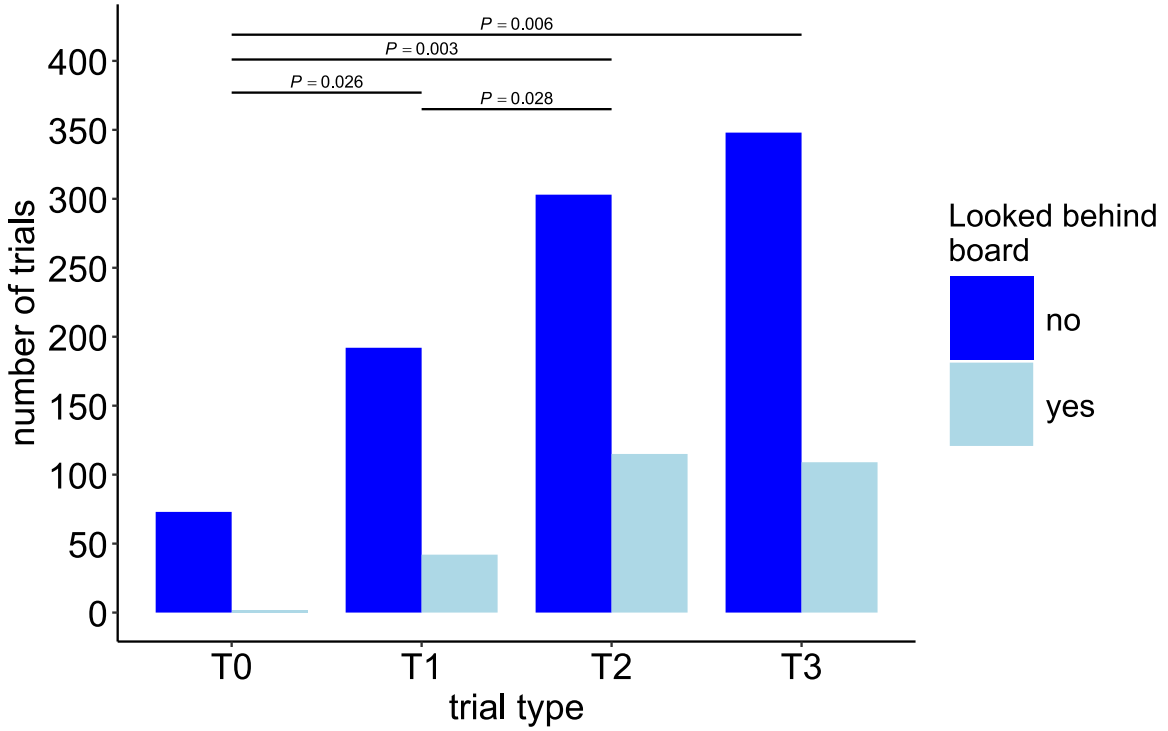

Figure 4. Mirror inspection behaviour in response to each of the four trial types (T0: mirror-only control, T1: food-only control, T2: mirror + food simulated single, T3: mirror + food simulated double), including all goose entries. Bars between trial types indicate significant differences in geese's likelihood of looking behind the board. There were no significant differences in the likelihood of looking behind a board between the trial types T1 and T3 (P = 0.185) and between T2 and T3 (P = 0.234).

Table 1. Output from a binomial generalized linear mixed model (GLMM) testing which factors influenced whether geese looked behind the board, including all goose entries. The model included dominance rank, trial type, entry number, sex, age, pairing status, and board number as fixed effects, and individual ID as a random effect.

Fixed effect	Estimate	SE	z-value	χ^2	df	P-value
(Intercept)	-2.53	0.76	-3.33			
Dominance Rank	-0.16	0.09	-1.76	3.10	1	0.078
Trial Type [T1]	2.02	0.74	2.72	17.58	3	**< 0.001**
Trial Type [T2]	2.57	0.73	3.52			
Trial Type [T3]	2.38	0.73	3.25			
Entry Number	-0.00	0.06	-0.08	0.01	1	0.940
Sex [M]	-0.23	0.17	-1.33	1.78	1	0.182
Age	-0.08	0.02	-3.94	15.55	1	**< 0.001**
Pairing Status [Y]	-0.19	0.18	-1.03	1.05	1	0.305
Board [2]	-0.68	0.19	-3.51	14.88	3	**0.002**
Board [3]	-0.01	0.21	-0.05			
Board [4]	-0.20	0.21	-0.97			

Significant P-values (< 0.05) are shown in bold. For trial type, the reference category is T0. For sex, the reference category is female (F). For pairing status, the reference category is unpaired (N). For board, the reference category is 1.

Table 2. Post-hoc pairwise comparisons comparing the likelihood of looking behind the mirror between each of the four trial types (T0: mirror-only control, T1: food-only control, T2: mirror + food simulated single, T3: mirror + food simulated double), including all goose entries.

Contrast	Estimate	SE	z-ratio	P-value
T0 – T1	-2.02	0.74	-2.72	**0.026**
T0 – T2	-2.57	0.73	-3.52	**0.003**
T0 – T3	-2.38	0.73	-3.25	**0.006**
T1 – T2	-0.55	0.21	-2.60	**0.028**
T1 – T3	-0.36	0.21	-1.68	0.185
T2 – T3	0.19	0.16	1.19	0.234

Significant P-values (< 0.05) are shown in bold and are adjusted for multiple comparisons using the Holm method.

Table 3. Output from a binomial generalized linear mixed model (GLMM) testing which factors influenced whether geese looked behind the board during trials with both food and mirror (T2 and T3), including all goose entries. The model included dominance rank, trial type, entry number, age, sex, pairing status, and board number as fixed effects, and individual ID as a random effect.

Fixed effect	Estimate	SE	z-value	χ^2	df	P-value
(Intercept)	-0.02	0.35	-0.05			
Dominance Rank	-0.14	0.12	-1.21	1.45	1	0.228
Trial Type [T3]	-0.21	0.17	-1.27	1.62	1	0.204
Entry Number	-0.05	0.07	-0.70	0.49	1	0.485
Age	-0.08	0.03	-3.22	10.38	1	**0.001**
Sex [M]	-0.20	0.22	-0.94	0.87	1	0.350
Pairing Status [Y]	-0.06	0.24	-0.24	0.06	1	0.810
Board [2]	-0.64	0.23	-2.83	11.16	3	**0.011**
Board [3]	0.04	0.23	0.17			
Board [4]	-0.20	0.25	-0.79			

Significant P-values (< 0.05) are shown in bold. For trial type, the reference category is T2. For sex, the reference category is female (F). For pairing status, the reference category is unpaired (N). For board, the reference category is 1.

6. Discussion

In this thesis, I investigated the factors influencing mirror inspection behaviour in greylag geese. As expected, the likelihood of looking behind the board was higher in the three food trials (T1: food-only control, T2: mirror + food simulated single, T3: mirror + food simulated double) than in the mirror-only control trial (T0: mirror with empty food tray), indicating that the presence of food is the major driver for greylag geese to look behind a board (prediction 1). The three food trials did not differ significantly from each other in their likelihood of mirror inspection (prediction 2), except that geese were more likely to look behind the mirror in T2 versus T1, suggesting a small added effect of the mirror stimulus. Younger geese were more likely to look behind the mirror than older geese and, contrary to my prediction, dominance ranking did not predict mirror inspection behaviour (prediction 3). The two mirror + food trials did not differ in their likelihood of mirror inspection, suggesting that the position of the food tray and the geese's capacity for object permanence did not affect this behaviour (prediction 4). Individual differences in the likelihood of mirror inspection behaviour were weakly but significantly repeatable (adjusted $R = 0.040$), indicating that some individuals were consistently more likely than others to look behind the mirror (prediction 5). This raises the possibility that mirror inspection is associated with personality traits like exploration.

Greylag geese were more likely to look behind the board when food was present, suggesting that their main driver for looking behind a board is their foraging motivation rather than interaction with their own mirror image. The ability to forage successfully, especially when food resources are sparse or hidden from view, plays a crucial role in survival across many species. It could also influence individuals to show unusual behaviour like looking behind a mirror to search for alternate food sources. The capability to use mirrors to locate hidden food or objects is also known from other species, including monkeys (*Macaca tonkeana* and *M.*

fascicularis) (Anderson, 1986), Asian elephants (Povinelli, 1989), dogs (Fukuzawa & Hashi, 2017; Howell et al., 2013), pigs (Broom et al., 2009; but see: Gieling et al., 2014), chicken (*Gallus gallus domesticus*) (Hillemacher & Tiemann, 2024), African grey parrots (*Psittacus erithacus*) (Lin et al., 2023; Pepperberg et al., 1995), and New Caledonian crows (Medina et al., 2011).

Mirror inspection was slightly more likely during the mirror + food simulated single trials (T2) compared to the food-only control (T1), suggesting a small added effect of the mirror stimulus. This may be because geese perceive the mirror image of the food as an additional food source that appears to be located behind the board. This would also explain why they almost never looked behind the mirror during the mirror-only control trials (T0) when no food was present. The lack of a significant difference between the food-only control (T1) and the second mirror + food trial (mirror + food simulated double, T3) could be explained by the habituation of the geese over time to the mirror stimulus. Additional experiments may be needed to clarify why the food-only control (T1) and the second mirror + food trial (T3) did not differ significantly in their likelihood of mirror inspection behaviour.

Age predicted the probability of mirror inspection behaviour, with younger geese more likely to look behind the mirror than older geese. Younger geese may be more motivated than older geese to search for alternate food sources; by foraging behind the board rather than at the food tray, they may be seeking to avoid competition with other flock members. In tufted capuchin monkeys (Westergaard & Suomi, 1995), bonobos (*Pan paniscus*) (Westergaard & Hyatt, 1994), and African grey parrots (Pepperberg et al., 1995), younger individuals also showed greater mirror inspection behaviour. Surprisingly, a goose's dominance ranking within the flock did not predict its likelihood of inspecting the mirror. Therefore, the geese's motivation to avoid perceived "opponents" by seeking out alternative food resources based on their own social rank cannot fully explain this behaviour.

The two mirror + food trials (T2 and T3) did not differ in their likelihood of mirror inspection, which suggests that the position of the food tray and, therefore, the geese's comprehension of object permanence had little effect on goose behaviour. Many inter- and intraspecific interactions are based on producer–scrounger relationships, where one individual (a scrounger) uses the behavioural investment of another (a producer) to exploit a limited resource (Barnard & Sibly, 1981). Individuals that forage in groups can either search for food sources by themselves (producing) or join food discoveries of other individuals (scrounging) (Kurvers et al., 2012). For the geese, the perception of the food pile size in the mirror, which is twice the size of a single food tray, could possibly influence their choice of food strategy. One single smaller pile (i.e. in the food-only control, T1) could favour producers but the perception of multiple smaller piles of food (i.e. mirror + food simulated double, T3) or one larger pile of food (i.e. mirror + food simulated single, T2) may be more profitable for scroungers.

The weak but significant repeatability of mirror inspection behaviour among individuals (adjusted R = 0.040) indicates that some individuals were consistently more likely than others to look behind the mirror. This suggests that mirror inspection could be associated with personality traits like exploration, boldness, aggressiveness, and sociability, all of which have previously been demonstrated in this study population (e.g. Kleindorfer et al., 2025; Kleindorfer, Krupka, et al., 2024; Kralj-Fišer et al., 2007; Kralj-Fišer et al., 2010). Some other studies with magpies, kea (*Nestor notabilis*), and Goffin's cockatoos also treat mirror inspection behaviours like looking behind a mirror as a type of exploration (Prior et al., 2008; van Buuren et al., 2019), which implies that individuals showing mirror inspection behaviour tend to search for food in novel locations (Kleindorfer et al., 2025). In our population of greylag geese, individuals that were first followers (i.e. the first flock member to follow a departing leader) during sub-group movement events were also more exploratory (less neophobic) towards a novel object and showed more mirror inspection behaviour (Kleindorfer et al., 2025).

Personality traits may also predict individuals' choice of preferred food strategy, including whether they use producing or scrounging tactics during foraging. In barnacle geese (*Branta leucopsis*), individual boldness (tolerance of risky situations such as the presence of a predator; Réale et al., 2007) influenced whether a goose used producer (finding food patches) or scrounger (joining patches) tactics (Kurvers et al., 2010). Shy individuals were more likely to scrounge than bold individuals and dominant geese were more successful in joining patches than subordinate geese (Kurvers et al., 2010). However, in a study of wild great tits (*Parus major*), whether individuals specialised in producing or scrounging was predicted by their sex, age, learning skills, and social factors like population density, but was not related to exploratory personality (Aplin & Morand-Ferron, 2017). Specifically, scrounging was more likely among females and adults, late arrivers within areas, and slower learners (Aplin & Morand-Ferron, 2017). Proportionally more scroungers occurred in larger subpopulations with a higher social density and they had higher network centrality and larger average group sizes than producers (Aplin & Morand-Ferron, 2017). Individual variation in personality could mediate differences in mirror inspection behaviour in greylag geese, perhaps mediated by individual differences in foraging strategy.

In conclusion, mirror inspection behaviour in greylag geese is mainly driven by the presence of food and is more frequently exhibited by younger geese. This helps us to understand geese's motivation for looking behind a mirror, providing important context on the mechanisms underlying this behaviour in a species that does not show mirror self-recognition. For future research in this species, it would be useful to explicitly test for correlations between mirror inspection and personality traits such as exploration or boldness. Further research examining mirror inspection in other non-self-recognising species will allow us to better understand this unique behaviour across a range of taxa.

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8. List of tables and figures

8.1 List of tables

8.2 List of figures

9. Supplementary tables and figures

Table S1. Key variables derived from the mirror experiment.

Variable	Definition
Date	Date of the trial (YYYY-MM-DD format)
Starting Time	Time when the trial started (24-hour format)
Board	Position of the board with the food tray within the greylag goose feeding area (1: Meadow, 2: Pond, 3: River, 4: Stones)
Trial Type	The type of trial conducted: mirror-only control = mirror revealed with empty food tray, food-only control = no mirror with full food tray, mirror + food simulated single = mirror revealed and full food tray pressed up against mirror, mirror + food simulated double = mirror revealed and full food tray 15 cm in front of mirror
Trial Type Day	The iteration of each trial type
Goose ID	Name of the focal goose
Sex	Sex of the focal goose (M = male, F = female)
Hatch Year	Hatch year of the focal goose
Entry number	The order of 5-min entry periods per subject and per feeder (range 1–7) on a given day
Look Behind Half	Number of half-looks behind the mirror board (defined as looking or moving behind the board and not returning to the front while continuing search behaviour)
Look Behind Full	Number of full-looks behind the mirror board (defined as looking or moving behind the board and then returning to the front while continuing search behaviour)
Look Behind Total No	Total number of looks behind the mirror (half-looks plus full-looks)
Look Behind	Whether the subject looked behind the mirror (Yes/No)

Table S2a. Number of trials per goose and per trial type across all mirror experiments (part 1).

Goose ID	Mirror-only Control	Food-only Control	Mirror + food simulated single	Mirror + food simulated double	Total number per goose
Amelie	3	1	5	3	12
Anthony	0	2	5	7	14
Babaco	0	7	6	4	17
Bacardi	4	5	6	15	30
Ballantine	0	4	3	5	12
Balmenach	0	6	4	3	13
Baptiste	1	4	8	5	18
Batate	0	2	4	2	8
Baycox	0	1	4	2	7
Bayou	0	1	4	0	5
BeakerParker	0	1	2	0	3
Belmont	0	1	5	3	9
Bernard	3	4	10	9	26
Besenstiel	0	2	6	5	13
Birne	1	2	6	5	14
Bolzano	0	1	0	1	2
Boris	4	0	4	1	9
Bregenz	0	0	1	1	2
BruceSpringsteen	0	2	4	15	21
Burglar	1	5	4	10	20
Dagobert	0	2	3	3	8
DaVinci	0	4	4	12	20
Demant	1	3	1	3	8
Diega	1	8	6	5	20
Dimitri	0	5	13	11	29
Disney	0	9	6	4	19
Dorothea	0	8	5	5	18
Dunja	2	5	3	2	12
Einstein	0	6	3	8	17
Emu	0	2	4	5	11
Erdbeere	0	1	7	3	11
Ericsson	0	1	3	4	8
Ernst	0	3	7	5	15
FairyTale	0	4	5	1	10
Floki	0	7	6	9	22
Frodo	1	3	1	3	8
Ginny	1	7	16	12	36

Table S2b. Number of trials per goose and per trial across all mirror experiments (part 2).

Goose ID	Mirror-only Control	Food-only Control	Mirror + food simulated single	Mirror + food simulated double	Total number per goose
Giovanni	2	4	12	5	23
Jafar	0	1	4	7	12
Joshua	1	2	2	3	8
Julian	0	1	1	3	5
Jurek	0	3	4	6	13
Karamell	0	4	3	5	12
Karolina	1	0	4	2	7
Kendo	0	1	4	0	5
Kendosson	0	0	2	1	3
Kiki	0	1	4	3	8
Koarl	0	1	4	6	11
Kokosnuss	0	5	8	8	21
Kolibri	6	1	3	2	12
Krummel	0	1	1	5	7
Lagertha	0	2	6	2	10
Lando	0	2	6	14	22
Lauffuss	1	3	0	4	8
Lauri	1	2	5	8	16
Lausbursch	2	2	9	10	23
Lazlo	1	1	6	0	8
Leia	1	4	2	4	11
LindyHop	4	5	8	5	22
Lionel	2	3	5	2	12
Longshanks	0	2	4	4	10
Lotta	3	1	7	6	17
Lukka	6	5	4	10	25
Lumpy	2	5	7	7	21
Luna	0	1	4	0	5
Lupin	0	3	6	4	13
Luzifer	2	2	6	8	18
Natalie	1	5	5	10	21
Oberlix	0	0	3	4	7
Odessa	0	1	2	3	6
Olaf	0	0	7	1	8
Olga	0	2	6	5	13
Orange	1	0	3	2	6
Ornella	0	1	4	6	11

Table S2c. Number of trials per goose and per trial type across all mirror experiments (part 3).

Goose ID	Mirror-only Control	Food-only Control	Mirror + food simulated single	Mirror + food simulated double	Total number per goose
Otmar	0	0	5	6	11
Pasha	2	2	7	4	15
Paso	2	0	3	1	6
Pistazie	0	4	1	5	10
Pudding	0	3	6	11	20
Rili	1	4	3	5	13
Severin	4	4	14	18	40
Sherlock	0	2	5	7	14
Simibear	0	6	1	7	14
Spatzle	0	0	1	7	8
Sturmwind	1	2	5	7	15
Taiga	1	3	1	5	10
Trevor	2	4	6	6	18
Triton	3	2	11	7	23
Unknown ID	0	1	0	0	1
Total number for all geese	**76**	**243**	**424**	**462**	**1205**

Table S3. Output from a binomial generalized linear mixed model (GLMM) testing which factors influence whether geese looked behind the board, only considering each goose's first entry per feeder per day. The model included dominance rank, trial type, sex, age, pairing status, and board number as fixed effects, and individual ID as a random effect. Data from the mirror-only control trials (T0) were excluded from analysis, because geese never looked behind the board during their first entry in T0.

Fixed effect	Estimate	SE	z-value	χ^2	df	P-value
(Intercept)	-0.73	0.42	-1.75			
Dominance Rank	-0.20	0.14	-1.44	2.07	1	0.150
Trial Type [T2]	0.64	0.29	2.32	5.06	2	0.080
Trial Type [T3]	0.49	0.29	1.69			
Sex [M]	-0.37	0.25	-1.48	2.19	1	0.139
Age	-0.08	0.03	-2.68	7.18	1	**0.007**
Pairing Status [Y]	-0.15	0.27	-0.57	0.33	1	0.566
Board [2]	-0.52	0.29	-1.81	6.88	3	0.076
Board [3]	0.17	0.31	0.55			
Board [4]	0.20	0.28	0.70			

Significant P-values (< 0.05) are shown in bold. For trial type, the reference category is T1. For sex, the reference category is female (F). For pairing status, the reference category is unpaired (N). For board, the reference category is 1.

Table S4. Post-hoc pairwise comparisons comparing the likelihood of looking behind the mirror between each of the trial types (T1: food-only control, T2: mirror + food simulated single, T3: mirror + food simulated double), only considering each goose's first entry per feeder per day. Data from the mirror-only control trials (T0) were excluded from analysis, because geese never looked behind the board during their first entry in T0.

Contrast	Estimate	SE	z-ratio	P-value
T1 – T2	-0.64	0.29	-2.23	0.077
T1 – T3	-0.49	0.29	-1.69	0.182
T2 – T3	0.15	0.24	0.65	0.517

The P-values are adjusted for multiple comparisons using the Holm method.

Table S5. Output from a binomial generalized linear mixed model (GLMM) testing which factors influenced whether geese looked behind the board during trials with both food and mirror (T2 and T3), only considering each goose's first entry per feeder per day. The model included dominance rank, trial type, age, sex, pairing status, and board number as fixed effects, and individual ID as a random effect.

Fixed effect	Estimate	SE	z-value	χ^2	df	P-value
(Intercept)	-0.11	0.45	-0.25			
Dominance Rank	-0.26	0.16	-1.63	2.66	1	0.103
Trial Type [T3]	-0.15	0.24	-0.63	0.39	1	0.530
Age	-0.08	0.03	-2.34	5.49	1	**0.019**
Sex [M]	-0.41	0.29	-1.41	1.99	1	0.159
Pairing Status [Y]	-0.13	0.32	-0.41	0.17	1	0.679
Board [2]	-0.49	0.33	-1.49	5.31	3	0.150
Board [3]	0.24	0.34	0.72			
Board [4]	0.14	0.34	-0.43			

Significant P-values (< 0.05) are shown in bold. For trial type, the reference category is T2. For sex, the reference category is female (F). For pairing status, the reference category is unpaired (N). For board, the reference category is 1.

Figure S1. Location of boards 1–4 during the mirror experiments. (a) Board 1 was located on the grassy meadow nearest to the Auingerhof, the former site of the KLF, north of the feeding area; (b) Board 2 was located in front of the pond nearest to the goose feeding area; (c) Board 3 was located closest to the river Alm; (d) Board 4 was located close to the white stones of the dry water channel. White lime stones marked the borders of the 2-m and 1-m zone around each board.

10. Appendix

Complete protocols for video coding mirror trials with Solomon Coder

Step 1:

- Open Solomon Coder (with Program Settings → Program Mode set to Workspace Config) and create a large window for the video and a table (click on Coding Options and choose Time resolution → 0.100 Sec. and Time format → 02:05.75).
- Create several buttons (by clicking the right mouse button below the black window for the video and by opening the button properties with another right click) for entrance into and exit from the 2-m and 1-m zones and for the variables *look behind half* (1/2) and *look behind full*.
- Create a button for comments (Coding options → Comments) to include the identity of the geese and other notes. For trials where the goose has not left the 2-m zone after the 5-min trial, create the button "Still in 2 m zone after 5 min".
- Click on the Program Settings and choose the following settings: Disable Internal Video Codec, Video Mode → VMR, Lingvo → English, Show Button Descriptions, Color Buttons, Color Coding sheet, Look for Updates Automatically, and Auto Backup. Click on Analyze → Output Preferences and choose the settings in the screenshot below (**Fig. A1**).

This coding configuration can be saved with File → Save Configuration As... and used for all videos (**Fig. A2**).

Step 2:

- Open the video to be analysed by clicking on File → Open Video (**Fig. A3**).
- Draw the borders of the 2-m and 1-m zone, using the white limestones for orientation, with the drawing tool  . You can also open the saved  drawing to the video  (**Fig. A4**).

Step 3:

- Activate the audio by clicking on this button  and start the video  .
- Set a new zero point at the start of the experiment (Sync → Set Zero Point) when the observer has revealed the mirror and/or filled up the food tray (depending on the trial type; **Fig. A5**). If a goose is already inside the 2-m zone when the trial starts, its behaviour is not analysed until it has left the 2-m zone and then returned.

Step 4:

- Play the video from the starting point until the first goose enters the 2-m zone with both feet, then click the "enter 2 m" button (**Fig. A6**). Listen to the colour bands spoken aloud by the observer and search for the corresponding goose ID. Then write the name of the goose in the comments section and click the comments button twice, so that it will be added to the table beside the entry "enter 2 m" (**Fig. A6**). Always compare the colour bands that you can see on the video with those narrated by the observers, in case of observer error.
- If the goose comes directly from next to or behind the board and enters the 1-m zone without passing the 2-m zone, click the button "enter 1 m" and write the name of the goose and the text "(next to board/mirror)".

- Write down the starting time for this 5-min trial (00:25.30 in the example below, **Fig. A6**), so that the end time for this trial will be at 5:25.30. To delete entries from the table, click the right mouse button, choose "Delete", and a red cell with "xxxxx" appears. To remove this, you also have to delete it in the same way, so that the cell is empty.
- If something unexpected happens during the experiment to distract the geese—for example, a car passing by or a flock of ducks suddenly taking flight—add a comment to the table. Sometimes, ducks forage beside the geese, but heterospecific interactions can be ignored during video coding.

Step 5:

- Continue to score the mirror trial. If the goose enters the 1-m zone, press the button "enter 1 m" and write a comment with the name; if it leaves the 2-m zone, press the button "exit 2 m" and write a comment with the name (**Fig. A7**). Optionally, add "(inside 5 min)" in the comment field if the goose re-enters the 2-m zone during the same 5-min trial, to more easily distinguish separate trials (**Fig. A7**).
- Watch the goose until it leaves the 2-m zone and goes out of sight or until the 5-min trial is over. If the goose is still inside the 2-m zone after 5 mins (at 5:25.30 in this example), press the button "still in 2 m zone after 5 min" and write the name of the goose as a comment. This will mark the end of the 5-min trial. When the goose eventually leaves the 2-m zone and subsequently returns, this will be the start of another 5-min trial (with a separate start and end time).

Step 6:

- After watching the goose for the first time during the 5-min trial and recording all entries and exits, re-watch the trial to observe any mirror inspection behaviour. This behaviour is only possible if the goose had previously entered the 1-m zone and directed its head towards the board.
- If a goose is inside the 1-m zone and looks or moves behind the board and doesn't return to the front while continuing search behaviour, press the button "look behind (1/2)" and leave a comment with the goose's name. If it looks or moves behind the board and then returns to the front while continuing search behaviour, press the button "look behind (full)" and add a comment with the name of the goose (**Fig. A8**). Mirror inspection behaviour is only considered valid if the behaviour was not directly caused by other geese—for example, in response to forward neck, chasing, or other aggressive displays.

Step 7:

- After completing a full trial, rewind the video until the start of the previous trial and then begin scoring the next trial in chronological order.
- To speed up or slow down the video, press this button next to the "play" button . The speed of the video can vary between 12.5% (1/8 speed of the original video) and 400% (four times faster than the original video), the latter of which is useful during periods when no geese are within the frame of the camera.
- Continue coding all entrances within 2-m of the feeder until the 55-min mark of the experiment; any new geese arriving after this time cannot be scored, because the video ends at the 1-hour mark before the full 5 mins can elapse. Optionally, mark the end time of the experiment with the comment "End of trial" at the 1-hour-mark (**Fig. A9**).

Step 8:

- After finishing behavioural coding for all trials during the 60-min experiment, save the coding sheet from Solomon coder as an arch-file. To do this, first click on Analyze → Select Output → Save Coding Sheet. Then click on File → Save Coding Sheet As… and take the name of the video that was coded (**Fig. A9**). Always open the coding sheet in Solomon Coder together with the right video, otherwise it will not work.

Step 9:

- To extract the data from the coding sheet, save them as an .csv file by clicking on Analyze → Save Output File As… and save it with the name of the video and "coding sheet" behind the name (**Fig. A10**). Optionally, these dataset files can then be converted into .xlsx format for additional data preparation and subsequent importation into R for statistical analysis.

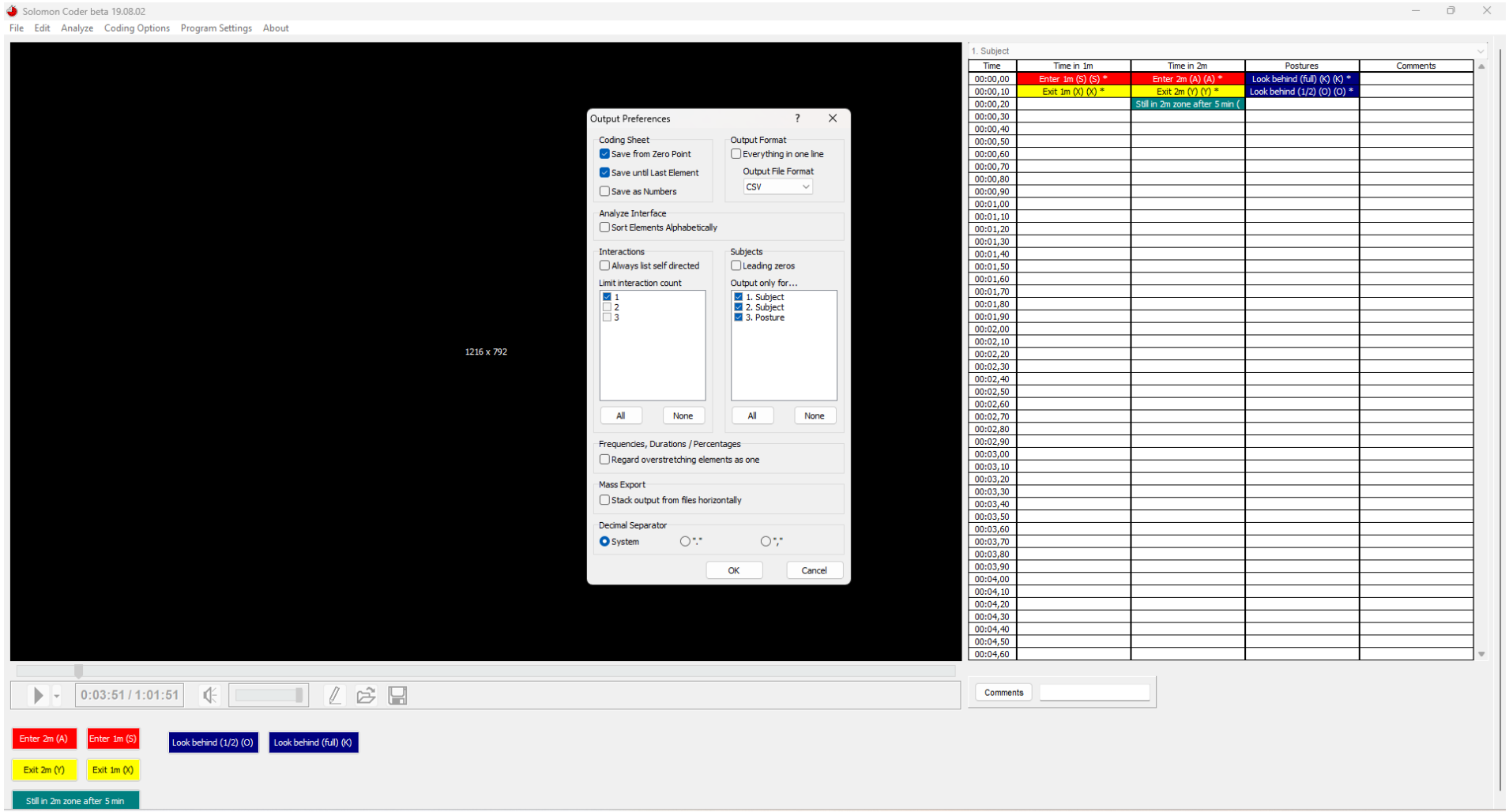

Figure A1. Screenshot while selecting output preferences.

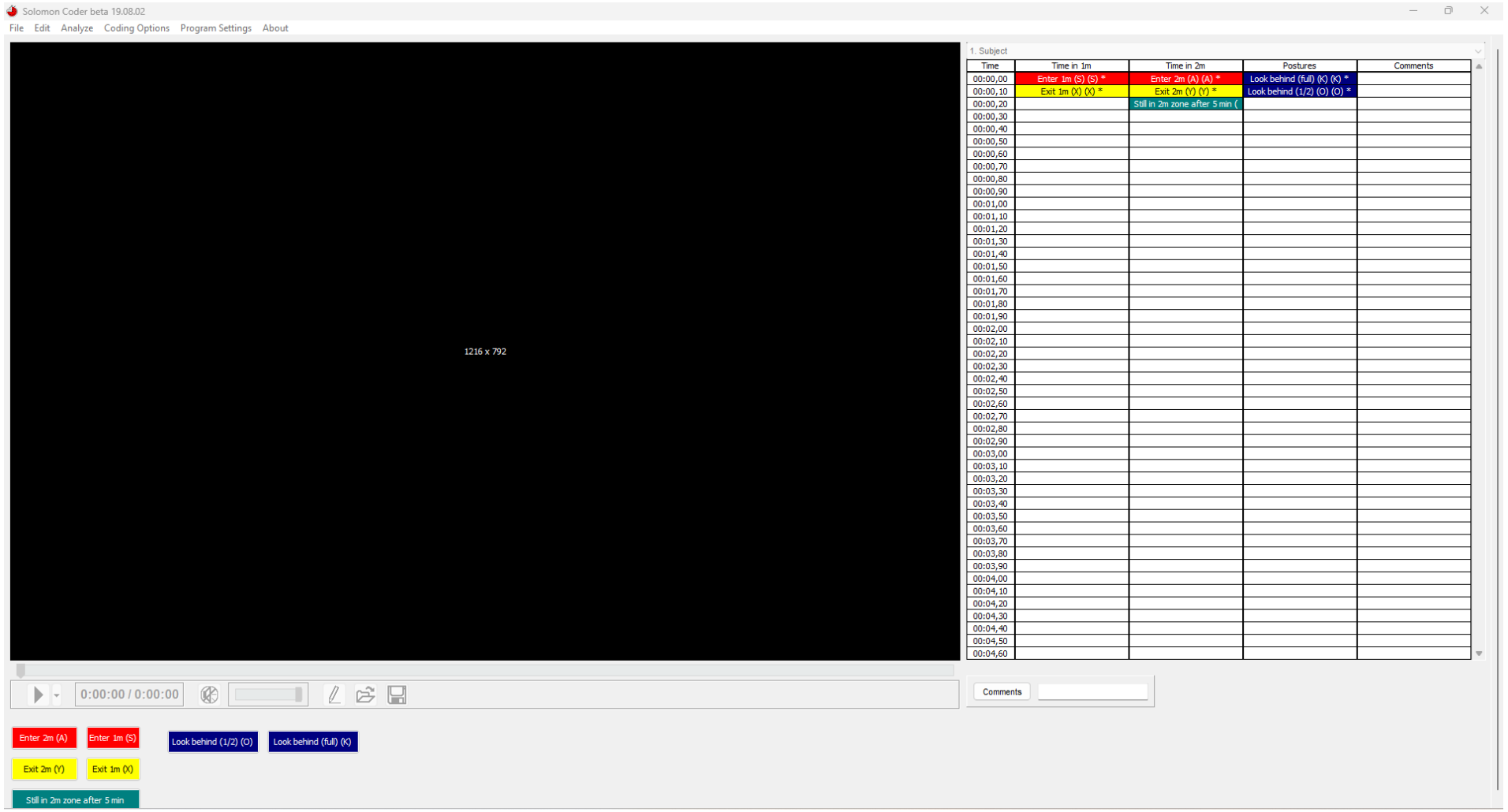

Figure A2. Screenshot of the final coding configuration, including a large window for the video (black screen on the left) and buttons to register goose behaviours, including entrances and exits from the trial zones and mirror inspection behaviours.

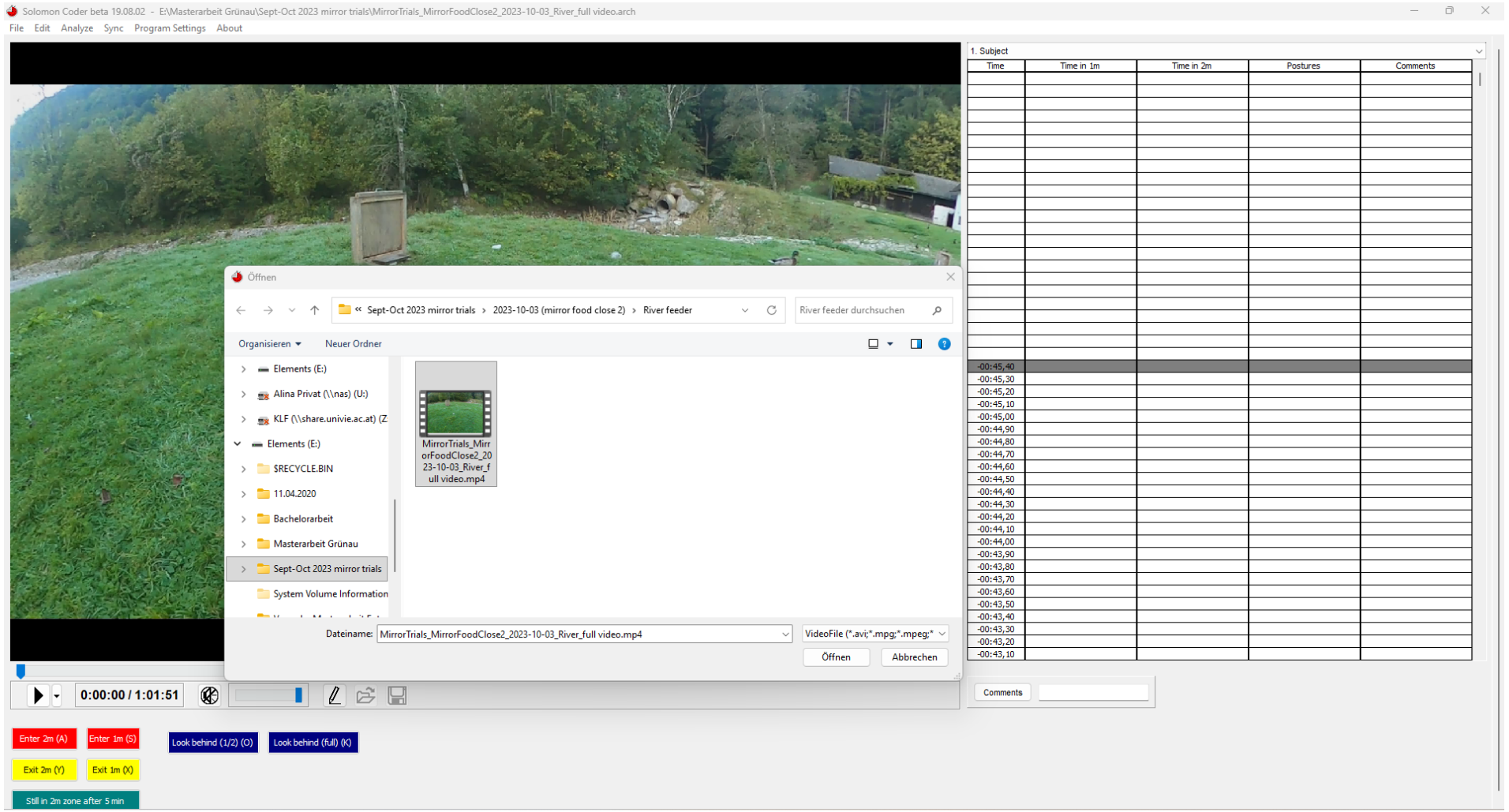

Figure A3. Screenshot of the window with the marked video that was opened into Solomon Coder.

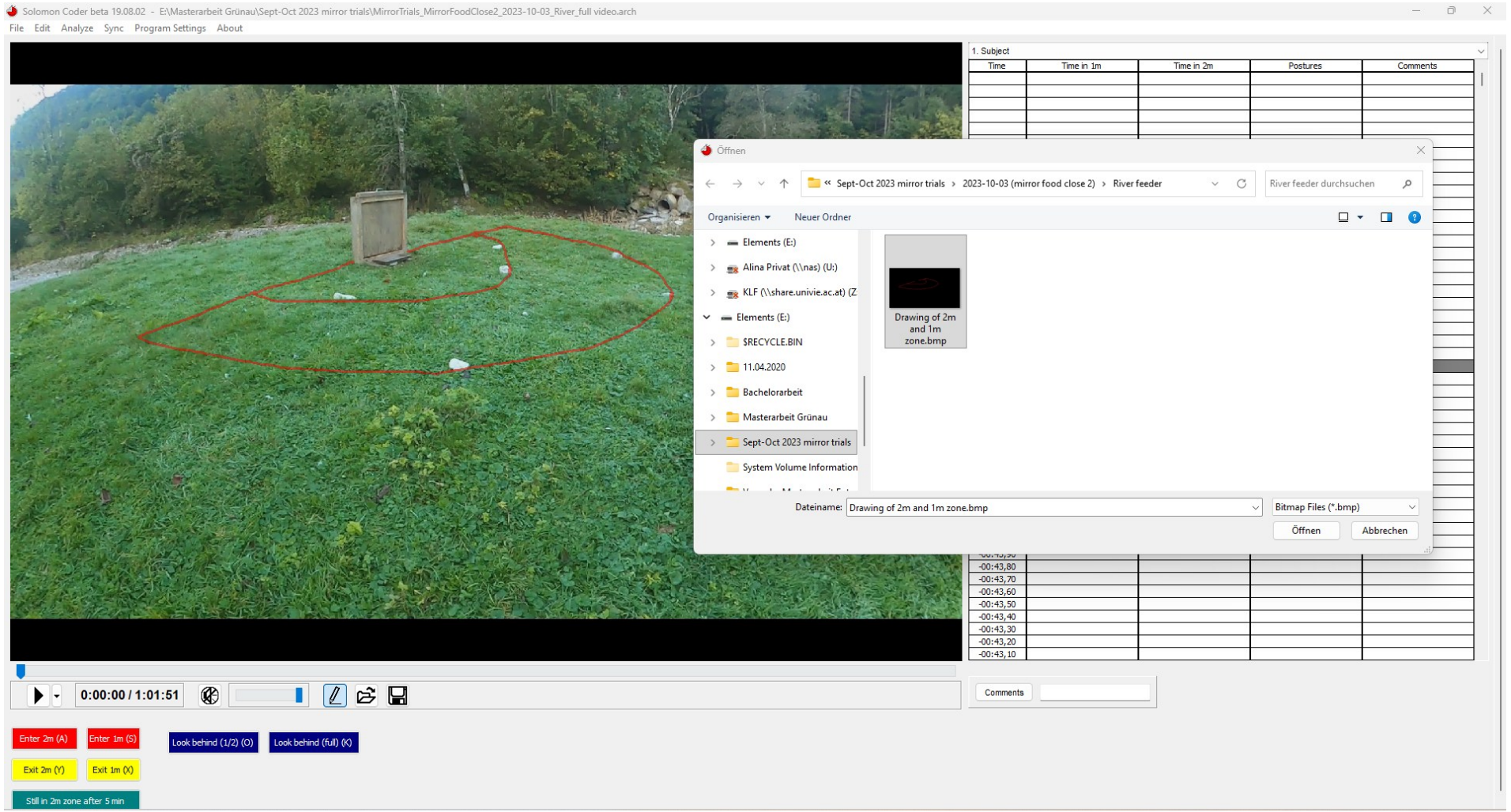

Figure A4. Screenshot of the window with the marked and previously-saved drawing of the borders of the 2-m and the 1-m zones (red lines in the background).

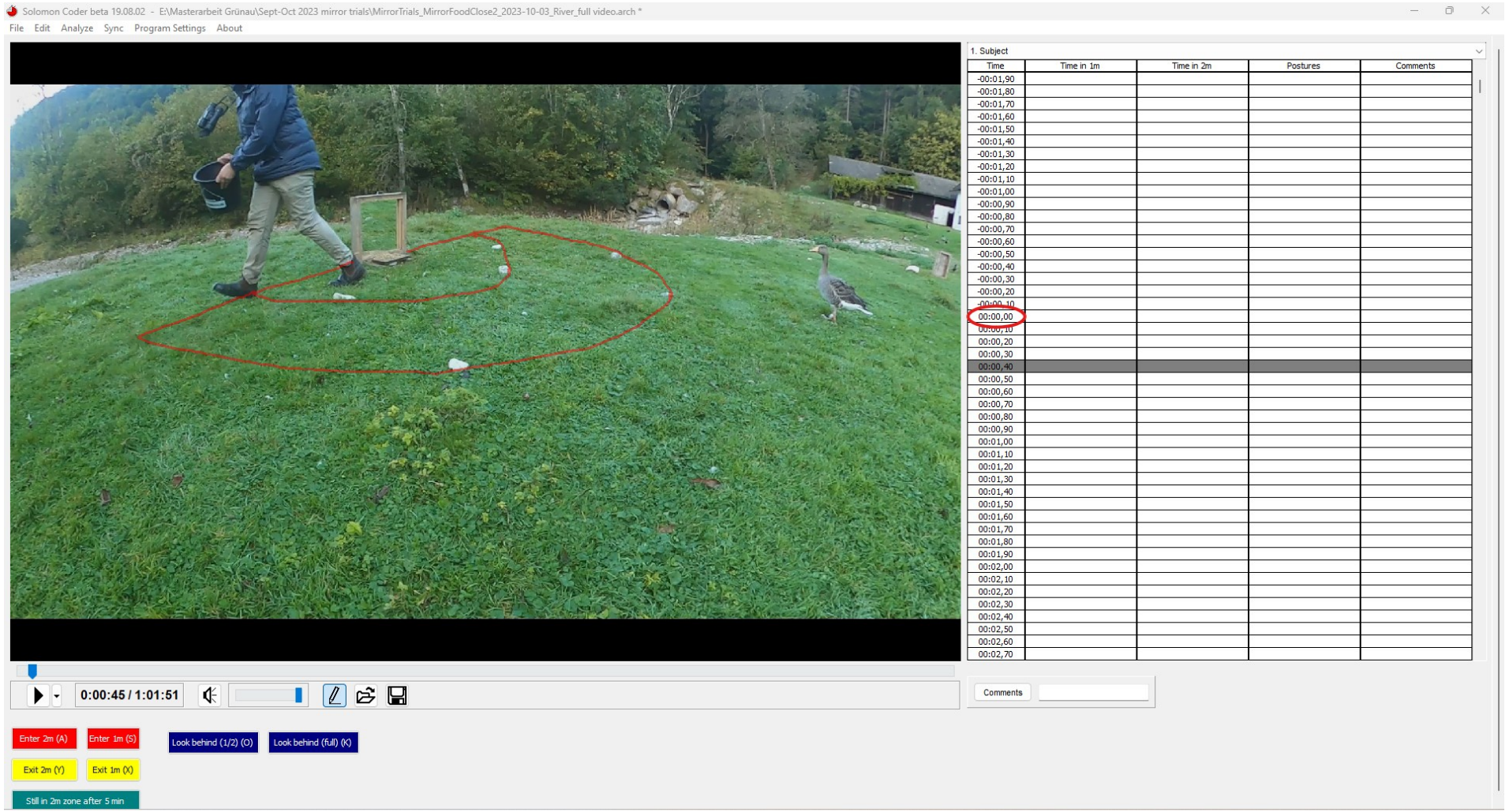

Figure A5. Screenshot of the start of the video and the new zero point (red circle).

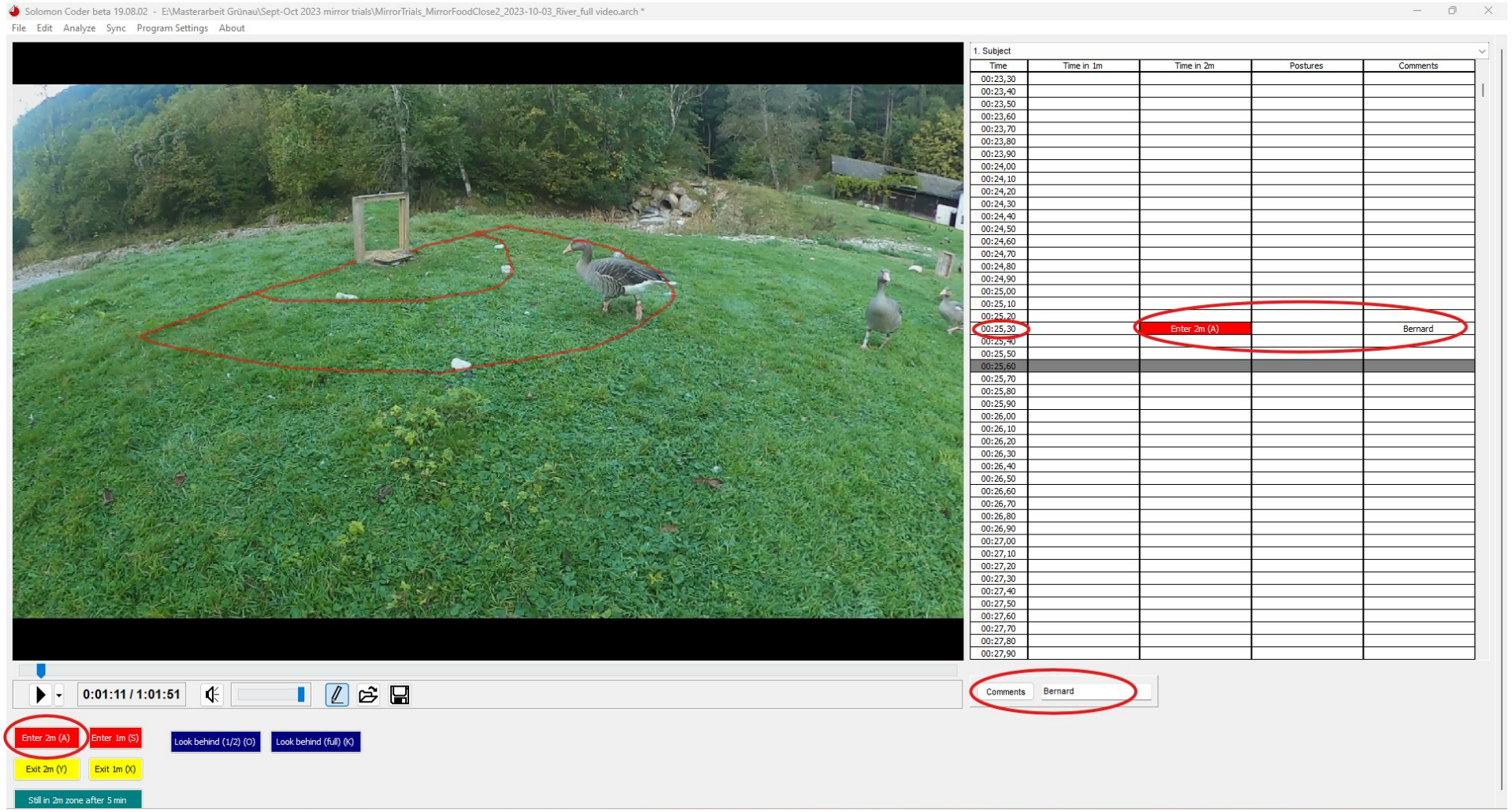

Figure A6. Screenshot of the entry of one goose (in this example: Bernard) into the 2-m zone with the starting time of this trial at 00:25.30, the button “enter 2 m”, the comment with the goose’s name, and the relevant entry in the data table on the right (red circles).

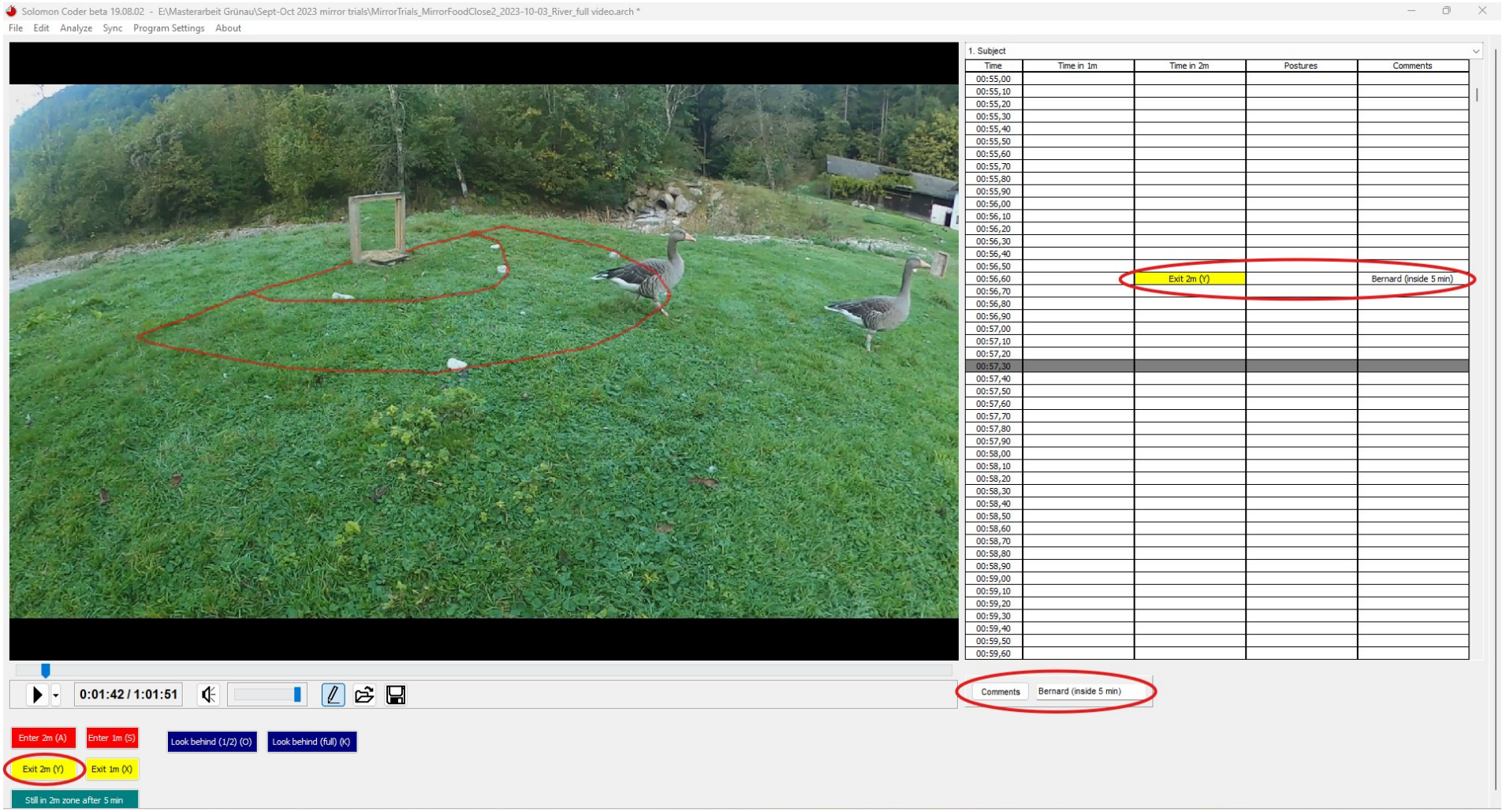

Figure A7. Screenshot of the exit of one goose (in this example: Bernard) from the 2-m zone, with the button "Exit 2 m", the comment with the goose's name and "(inside 5 min)" to make clear that this exit is still inside the same 5-min-trial, and the relevant entry in the data table on the right (red circles).

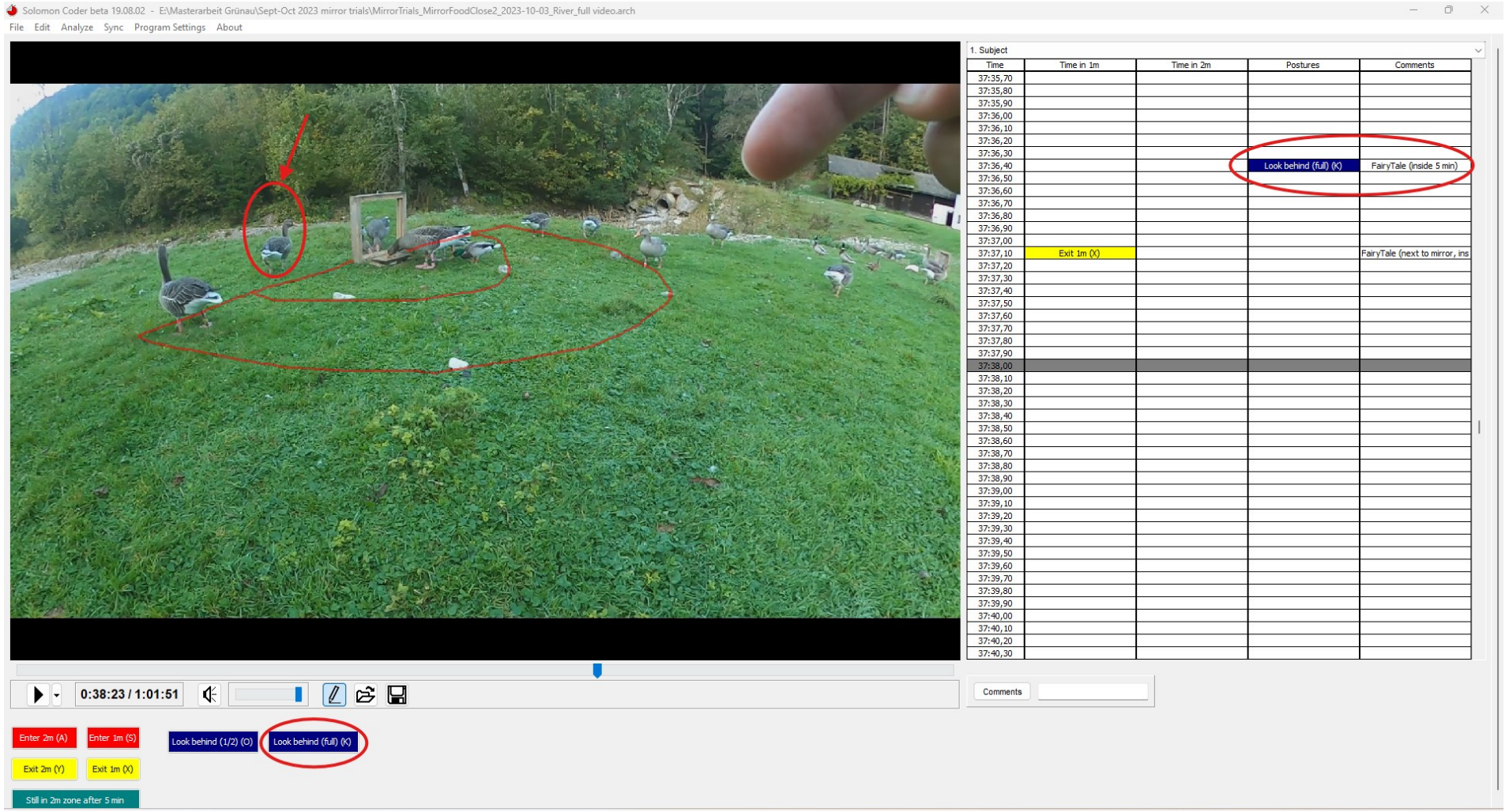

Figure A8. Screenshot of a goose (in this example: Fairy Tale) showing mirror inspection behaviour, here by looking and moving behind the board and then returning to the front while continuing search behaviour (red circle with red arrow). This behaviour was scored with the button "look behind (full)" and the relevant entry in the data table on the right (red circles).

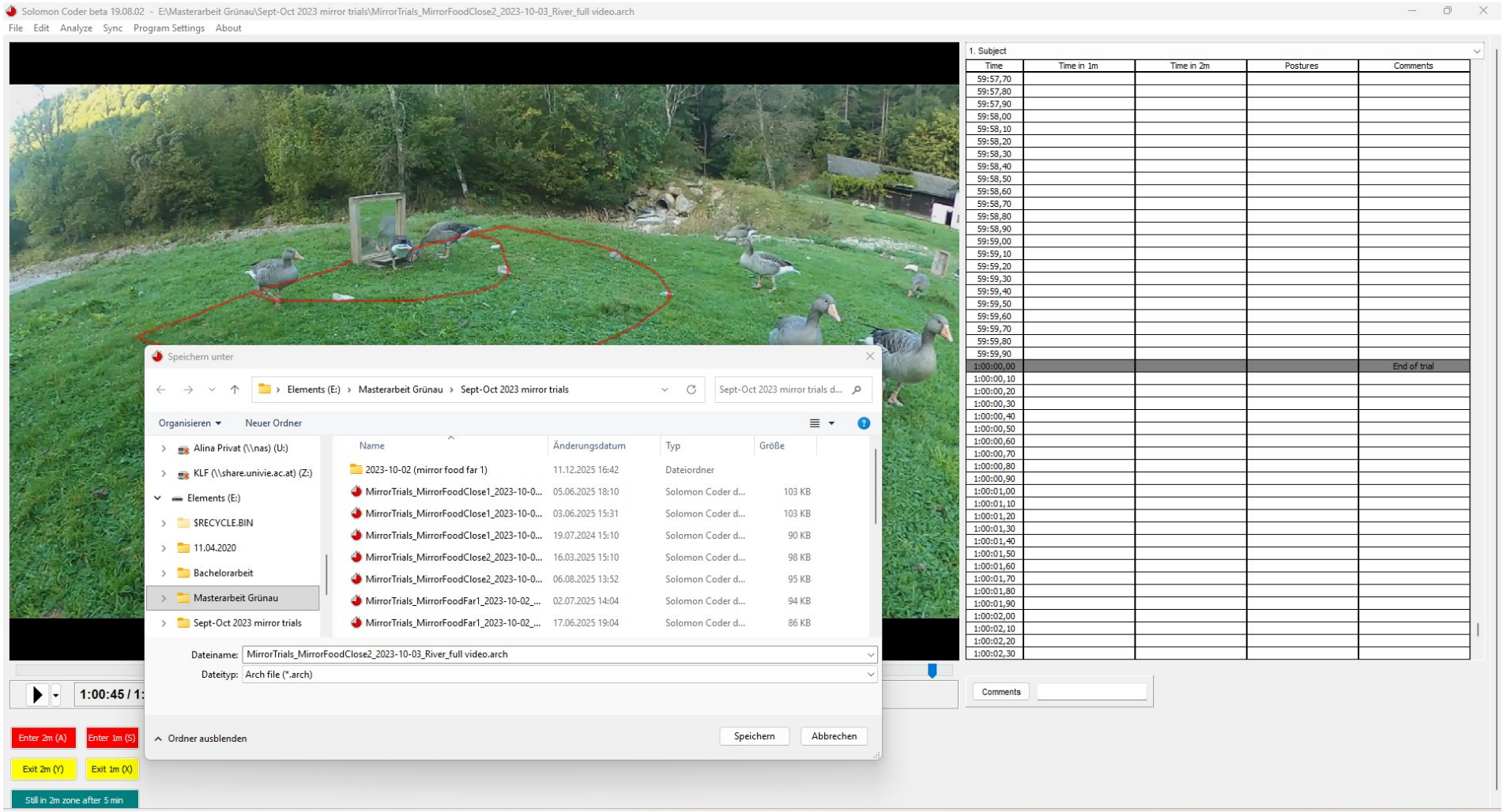

Figure A9. Screenshot while saving the coding sheet from Solomon Coder as an .arch file, using the name of the video that was coded.

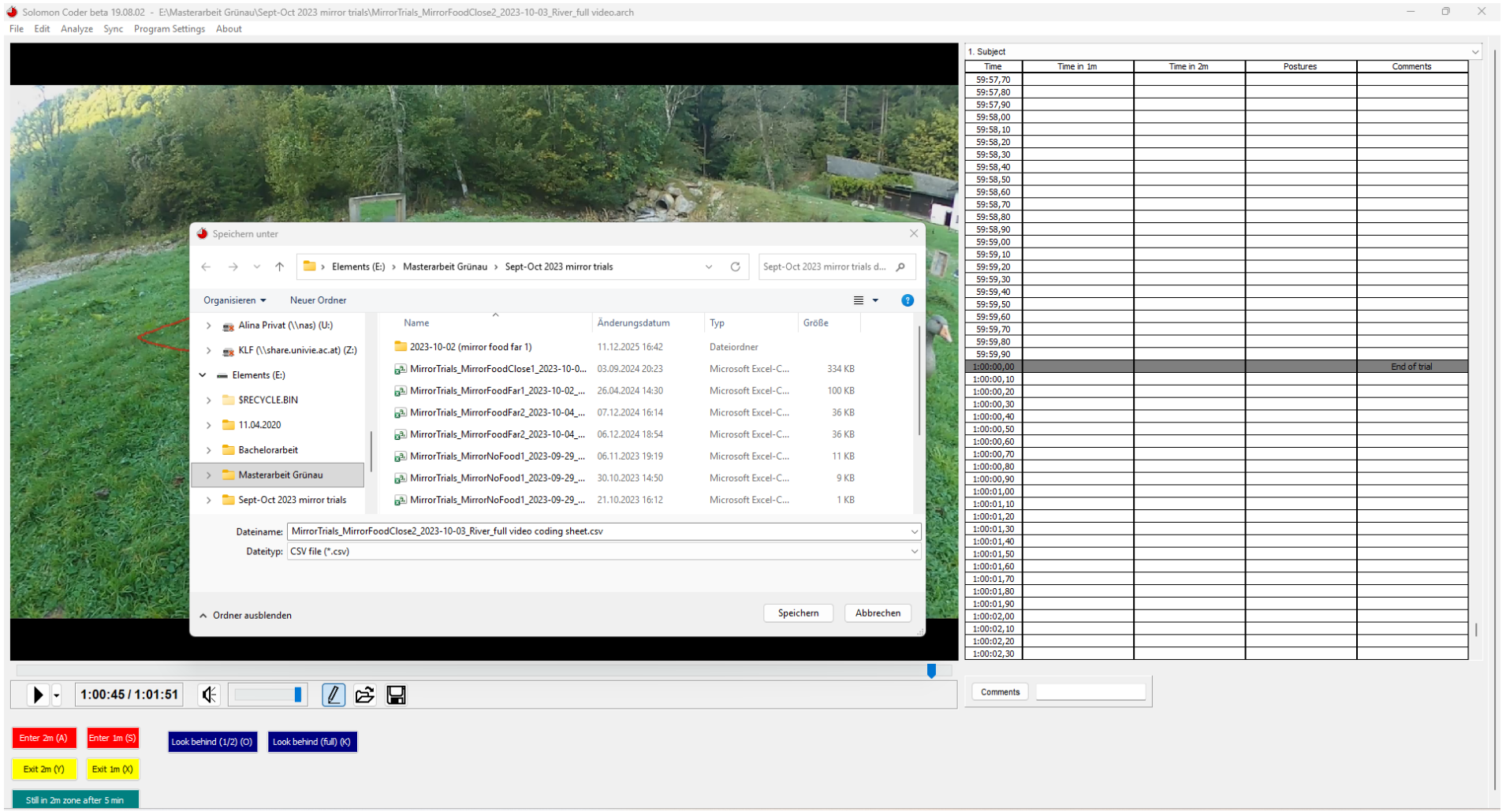

Figure A10. Screenshot while saving data from the coding sheet as a .csv file, using the name of the video with the suffix “coding sheet”.