Increasing foraging times with appetitive and consummatory foraging enrichment in grey parrots (*Psittacus erithacus*)

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ABSTRACT

Foraging enrichment is considered one of the most effective ways to enhance expression of species-typical behaviours and prevent the development of abnormal (repetitive) behaviours in captive animals. However, foraging enrichments for parrots have thus far not been able to approximate natural foraging time budgets nor completely eliminate abnormal behaviours such as feather damaging behaviour. This might be related to the design of currently available foraging enrichments, which generally stimulate a subset of foraging activities rather than foraging behaviour in its entirety. We therefore designed a two-component foraging enrichment that addressed both the appetitive and consummatory phases of foraging. To evaluate whether foraging times would approximate those in the wild (4–8 h/day), we studied the effect of the separate and combined components on foraging behaviour in 12 healthy grey parrots (*Psittacus erithacus*) using a balanced cross-over design. Parrots were provided food by means of the appetitive (APP), consummatory (CONS), and combined (APP+CONS) component(s) of the foraging enrichment, and in a food trough that served as a control (CTRL; no enrichment) for 30 days per test condition. The time spent on foraging was evaluated on days 2, 14 and 30 in all four test conditions using continuous focal sampling. Each of the single components (APP or CONS) increased daily foraging times from 2 to 3 h per day (CTRL: 121 ± 16 min/24 h, APP: 176 ± 31 min/24 h, CONS: 194 ± 26 min/24 h), while the combined enrichment doubled daily foraging times (APP+CONS: 234 ± 42 min/24 h), thereby approaching natural foraging time budgets. Foraging times remained steady over the 30 days, indicating no habituation or change in use of the enrichments throughout this period. These results demonstrate the importance of providing both appetitive and consummatory activities to generate effective foraging opportunities for parrots. Such a bottom-up approach could be beneficial for other (parrot) species as well.

1. Introduction

In many animal species, including parrots, foraging behaviour is assumed to be a behavioural need or priority (Osborne, 1977; Hughes and Duncan, 1988; Inglis et al., 1997, 2001). Parrots are willing to work for food, even when identical food is freely available (i.e., contra-freeloading; Coulton et al., 1997; Smith et al., 2021), and are motivated to gain access to foraging enrichment (Rozek and Millam, 2011; van Zeeland, 2013). Studies suggest that parrots have an intrinsic motivation to put effort in acquiring and handling food items (Rozek et al., 2010; James et al., 2021), which can – at least in part – be explained by their diet, ecology and evolution (Gygax and Hillmann, 2018). The

granivorous diet of most parrots requires a high degree of (time-consuming) exploration and manipulation of food items with the beak, tongue and feet, so-called podomandibulation (Rozek et al., 2010; Rozek and Millam, 2011; van Zeeland et al., 2013; James et al., 2021; Mellor et al., 2021).

Captive situations frequently lack opportunities to fulfil the aforementioned foraging 'needs' (Hughes and Duncan, 1988; van Zeeland et al., 2009; Rodríguez-López, 2016). Where wild parrots spend between 4 and 8 h per day on foraging with activity peaks in the early morning and late afternoon (e.g., Gilardi and Munn, 1998; Symes and Perrin, 2003; Salinas-Melgoza and Renton, 2005; O'Hara et al., 2019), captive parrots often spend less than one hour per day on foraging (e.g. Rozek

et al., 2010; van Zeeland et al., 2013). This in turn can increase the risk of parrots developing abnormal (repetitive) behaviours such as feather damaging behaviour (Meehan et al., 2003, 2004; Garner et al., 2006; van Zeeland et al., 2009; Mellor et al., 2018, 2021). As such, provision of foraging enrichment is advised as this both enables display and fulfilment of species-typical foraging behaviours and needs, and helps to prevent or reduce abnormal (repetitive) behaviours (Newberry, 1995; Swaisgood and Shepherdson, 2005; Shyne, 2006; Mason et al., 2007). Several studies have shown that providing foraging enrichment to parrots stimulates exploratory and foraging activities and can significantly increase times spent on foraging up to 2 or 3 h/day (Blue-and-yellow macaw: James et al., 2021; Lear's macaw: de Azevedo et al., 2016; Orange-winged Amazon parrot: Meehan et al., 2003; Rozek et al., 2010; Golden parakeet: Clyvia et al., 2015; Grey parrot: Lumeij and Hommers, 2008; van Zeeland et al., 2013; Red-tailed black cockatoo: Fangmeier et al., 2019). However, enrichment strategies thus far are unable to meet time budgets of wild parrots (4–8 h/24 h), which could explain why foraging enrichment at best reduces but regularly fails to completely eliminate abnormal (repetitive) behaviours such as feather damaging behaviour, as suggested by an incomplete recovery of the plumage (van Hoek and King, 1997; Meehan et al., 2003; Lumeij and Hommers, 2008; Peng et al., 2014). These observations therefore indicate that current foraging enrichment strategies need to be reconsidered or refined to increase their overall efficacy.

Foraging enrichment for parrots can involve a variety of different strategies, items and toys that stimulate the bird to search, procure, extract or process food (Rozek et al., 2010; van Zeeland et al., 2013; James et al., 2021). However, foraging enrichment frequently only stimulates a small subset of foraging activities. As a result, captive parrots spend less time on searching, procuring, extracting, and manipulating their food compared to wild conspecifics. It has been suggested that the intrinsic motivation to forage can be satiated if an animal is able to perform and experience both the appetitive (i.e. exploration, search and procurement of food) and consummatory (i.e. manipulation, selection and actual consumption of food) phases of foraging (Hughes and Duncan, 1988; Jensen and Toates, 1993; Berridge, 1996; Polley, 2015). An enrichment that incorporates both activities is likely to positively affect foraging times due to increased diversity and complexity of foraging tasks. In addition, an enrichment stimulating both appetitive and consummatory behaviour could enable the parrot to display innate foraging behaviours and exert more control over its environment, thereby meeting its behavioural foraging 'needs' and leading to improved welfare (Broom, 1986; Mellor, 2016; Arndt et al., 2022).

Of the parrot species that are commonly kept as companion, grey parrots (*Psittacus erithacus*) in particular are prone to developing feather damaging behaviour (van Zeeland et al., 2009; Gaskins and Hungerford, 2014; Jayson et al., 2014; Greenwell and Montrose, 2017; Acharya and Rault, 2020; Ebisawa et al., 2021). Grey parrots are highly social species, living in groups of up to ten thousand individuals near the equator in Africa in lowland rainforest, montane forest and wooded savanna (Parr and Juniper, 2010). They communicate with conspecifics via contact calls while foraging, and maintain strong, long-term monogamous bonds with their mate (de Grahl, 1987; Chapman et al., 1993). Dependent on the season, grey parrots have to travel larger distances between their roosting and feeding grounds, where they search for fruits, seeds, and flowers (Chapman et al., 1993; May, 2001). These aspects might explain the grey parrots' high cognitive and problem solving abilities (e.g., Pepperberg, 2004; Péron et al., 2011; Pepperberg et al., 2013), which places them among the most intelligent species of birds, puts high demands on their captive living environment, and likely renders them highly susceptible to developing feather damaging and other problem behaviours in captivity. Mellor et al. (2021) previously demonstrated a link between foraging style and feather damaging behaviour, indicating grey parrots to be a suitable model to further study the effect of increasing diversity and complexity of foraging behaviours using

enrichment.

In our study, we therefore used grey parrots to test a new foraging enrichment that we designed to evaluate whether increasing diversity and complexity of foraging tasks would allow us to approximate natural time budgets and activities of wild parrots. This new enrichment consisted of two components that would stimulate both the appetitive (simulating travelling, searching, exploration and selection; component APP) and consummatory (simulating extraction and manipulation of food items including podomandibulation; component CONS) foraging activities. Daily foraging times and food consumption were evaluated for each separate component and the components together in a case-control, cross-over study in 12 grey parrots (*Psittacus erithacus*) over 30-day periods.

2. Material and methods

2.1. Ethical approval

Ethical approval for this study was obtained from the Dutch Central Authority for Scientific Procedures on Animals (CCD) (AVD1080020184628) and the Animal Welfare Body in Utrecht (IvD) (protocol 4628–1–1). After completing this study, the parrots were returned to their regular aviaries.

2.2. Animals and housing

2.2.1. Animals

Twelve adult, non-breeding parrots from the research flock at the Faculty of Veterinary Medicine (Utrecht University, The Netherlands) were used in this study (five males, seven females; age range 5–11 years (median 8.5 years); body mass range 415–600 g). They were housed in groups of six in outdoor aviaries with an indoor compartment (heated in winter) and were therefore adapted to the Dutch climate. Seven parrots had previously taken part in another foraging enrichment study (van Zeeland et al., 2013). Results of the latter study were used to determine the sample size for the current study: a corrected α of 0.0125 (Bonferroni correction for *post hoc* testing of four conditions), a power of 0.80, and an interindividual variation between test conditions of 54 min (highest SD from van Zeeland et al., 2013) revealed that a sample size of 12 parrots per group would be enough to demonstrate statistical significance if there would be a true difference of at least 60 min/24 h in foraging times between the four test conditions.[1]

All parrots were clinically healthy based on a physical examination, faecal examination and testing on specific pathogens (PBFD, polyomavirus, bornavirus, herpesvirus, *Chlamydia psittaci*) and none of the birds showed signs of abnormal (repetitive) behaviour (e.g., sham/bar chewing, route tracing, weaving, somersaulting, feather damaging behaviour; Mellor et al., 2018).

2.2.2. Housing and nutrition

Multiple parrots entered the test simultaneously and were housed in the same room. For independent data collection, they were individually housed in standard-sized cages (L×W×H: 50 ×80 ×100 cm) with visual barriers placed in between cages; vocal contact remained possible. The cages were furnished with two wooden perches on different heights, one water bowl (~200 mL), one food trough and, depending on the test condition, the experimental foraging enrichment. The cage bottoms were covered with newspapers, which were renewed daily. Lights were on from approximately 7:00 h until 21:00 h (14L:10D), though natural light was also available through opaque windows. As a standard procedure, a radio with middle of the road music was provided during light hours (connected to the same timer as the lights). Heating and air

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[1] Software used for the sample size calculation: http://www.stat.uiowa.edu/~rlenth/Power/index.html

conditioning were available to maintain room temperature as stable as possible, with daily and seasonal fluctuations occurring (median temperature [Q_1-Q_3]: 18.1 [16.3–22.0] °C). On rare occasions, weather extremes led to larger fluctuations of the room temperature (minimum 10.6 °C, maximum 32.6 °C) as climate control measures could no longer maintain the preferred room temperature (15–25 °C). During these times, parrots were carefully monitored for signs of cold (e.g. ruffling of feathers, shivering) and heat stress (e.g. panting with open beak, extended wings). Signs of heat stress were observed occasionally (when >30 °C), which lead to a temporary suspension of the study until the parrots' behaviour returned to normal.

During daily caretaking (9:00–11:00 h), the cages were cleaned, parrots were misted with water using a nebulizer, and their food (Nutri-Berries, Lafeber Company™) and water (available ad libitum) were refreshed according to protocol.

The parrots were trained to voluntarily step on a scale (standard digital kitchen scale, 5000x1g) in their cage in return for a fruit reward (grape, apple, or orange) to monitor their body mass (see Supplementary material S1). All parrots were closely monitored throughout the study to ensure optimal health, which amongst others included daily monitoring of behaviour, reactivity, food and water consumption, production of faecal matter, and body mass. In case of unusual changes in health, posture or activity, an avian specialist was consulted and, if needed, the parrot would be suspended from the study until deemed healthy.[2]

2.3. Experimental setup and procedure

2.3.1. Study design and test conditions

Four foraging conditions were compared: one control condition and three enrichment conditions. The foraging enrichment in this study consisted of two components: the appetitive and the consummatory component. These two components were offered separately and combined, resulting in the following four test conditions: appetitive enrichment (APP), consummatory enrichment (CONS), two-component enrichment (APP+CONS), and a control condition (CTRL; no enrichment) (Fig. 1). The 12 parrots were assigned a random test order based on a case-control, cross-over, balanced Latin square design.

During the control condition (CTRL), parrots were provided with 50 g crushed Nutri-Berries provided in a food trough (which is a little more than their daily requirement as advised by Lafeber Company™). No further enrichment was provided.

The appetitive component (APP) of the enrichment consisted of an automated device which required the parrot to perform a multistep operant task to obtain food. The parrot had to drop a marble in a PVC marble track which was equiped with 3 obstacles. The action sequence that the parrot had to perform to obtain food was: 1) pick up a marble from the food trough; 2) transport the marble to the opening of the marble track; 3) put the marble in the marble track; 4) manipulate three levers with the beak (respectively rotate, lift and pull) to remove obstacles from the marble track that hindered free passage of the marble; 5) walk/climb towards the food trough and wait for deliverance of food; and 6) search, select, and eat out of the marble-filled trough. After the third obstacle, the marble would pass an optic sensor which activated a food dispenser, and fell into the food trough together with the food and other marbles. Each activation of the dispenser resulted in approximately 1.3 g of crushed Nutri-Berries (~3% of daily food intake). The dispenser was filled with 80 g of food (compared to 50 g in the control condition) to ensure that the scoop in the food container would pick up

and deliver the same amount of food with each activation. Otherwise, if the food container became emptier throughout the day, the scoop would pick up and deliver less than 1.3 g.

The consummatory component (CONS) of the enrichment consisted of handcrafted food capsules made from honeycomb cardboard (Axxor Core C8 T 8.0 mm with ~8x8mm cells, Axxor B.V., Zwolle, The Netherlands) that were filled with crushed Nutri-Berries and sealed with white paper (paper: BioTop 3 Next A4 naturel 160 g, Mondigroup, Addlestone, UK; glue: Bastelkleber, Stanger Produktions- und Vertriebs-GmbH & Co KG, Espelkamp, Germany). The capsules were approximately 40x40x10mm (L×W×H) and each contained approximately 1.3 g of food, evenly spread over approximately 30 cells. A total of 50 filled and 5 empty capsules were provided in the trough (the empty capsules were added to standardize the number of capsules in the CONS and APP+CONS conditions; see below). In order to obtain the food, the parrots had to pick up and manipulate the capsules with their beak to open the food-containing cells.

For the APP+CONS condition, the two components were offered together. In this condition, the parrot had to activate the food dispenser (component APP) in a similar manner as described for APP, but instead of the dispenser being filled with crushed Nutri-Berries, it was filled with food capsules (component CONS). The capsule dispenser contained 50 filled capsules with five empty capsules on top. The empty capsules were added to signal to the parrots that they would no longer receive food.

2.3.2. Timeline

The parrots were first habituated to their new environment and daily routine for at least 7 days (up to 14 days if the individual remained apprehensive). Subsequently, a training period commenced during which the parrots were trained to 1) step on a scale for daily monitoring of body mass; and 2) engage with the foraging enrichment (see Supplementary material S1 for a full description of the training). Dependent on their motivation, parrots were trained one to three times daily, with each training session lasting around 10–30 min. Training was deemed complete when the parrots could independently obtain their daily intake of food from the enrichment prior to testing. The visual barriers were then put in place and the parrots started a pre-test acclimatisation period of 7 days. This period was instigated for three reasons: 1) to ensure that the parrot could consistently obtain its daily food requirement from the enrichment without cues from the trainer (the 'Clever Hans' effect); 2) to enable acclimatization to the visual barriers, which helped to ensure that the behaviour and food consumption would not be altered by this change; and 3) to acclimatize the parrot to the lack of visual contact with conspecifics, thereby avoiding an added effect of solitary housing on the behaviour or food consumption. This 7-day pre-test acclimatisation was directly followed by a 30-day test period, during which the measurements took place.

2.3.3. Measurements

Each parrot was recorded continuously with an HD camera system with night vision (Bascom, Nieuwegein, The Netherlands) that was installed on the wall, approximately 2 m away from the parrots, to evaluate the daily time spent on foraging behaviours (min/24 h) using a standardized ethogram (see Table 1). Three days out of 30 days were selected for behavioural analysis, representing the early (day 2), middle (day 14), and late (day 30) phase of the test period. Parrots were observed using continuous focal sampling for blocks of approximately 24 h: observations started when the food in the cage was refreshed and ended the next day when the food was removed, and the cage was cleaned. Behavioural observations were carried out using the software program BORIS (Friard and Gamba, 2016) by three observers (MB, AM, IdH). Within- and between-observer agreement were tested prior to data collection (see 2.4. Statistical analysis).

Food consumption was measured daily by weighing and counting leftovers in the food trough and/or dispenser (i.e., grams of crushed Nutri-Berries in CTRL and APP, and number of capsules in CONS and
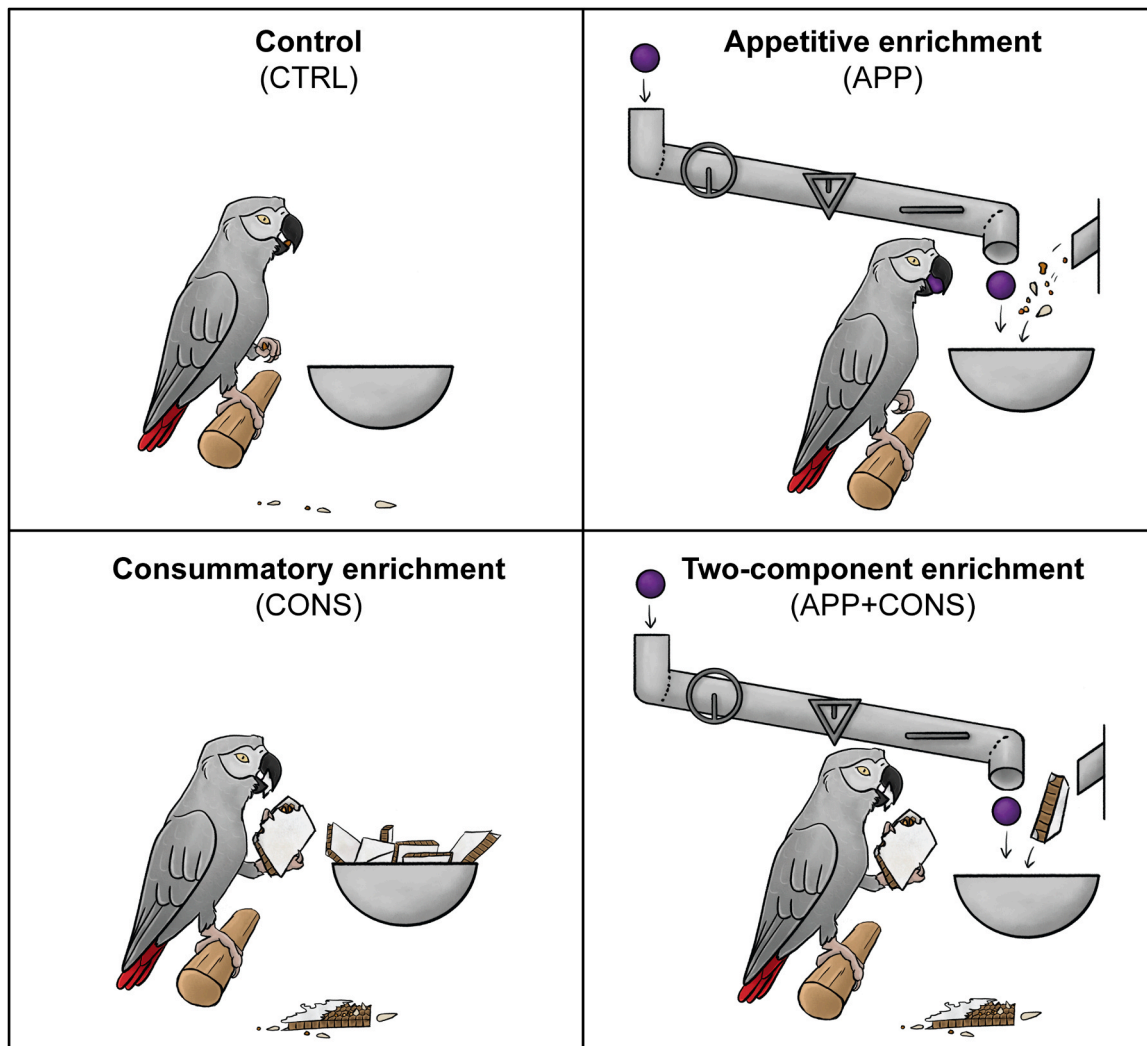
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[2] This occurred once (parrot #3, test condition APP+CONS, test day 13: toenail injury). The parrot received oral analgesia on test days 13, 14 and 15. On day 13, the parrot was given 50 g free food alongside the enrichment. On days 14 and 15, food consumption from the enrichment and (foraging) behaviour had returned to baseline, after which the bird was placed back in the test.

Fig. 1. Illustration of the four test conditions. During the control condition (CTRL), parrots were provided with free food in a food trough. During the appetitive (APP) and two-component condition (APP+CONS), the parrots had to activate a dispenser by leading a marble through a marble track that was equipped with three obstacles (rotate, lift and pull) to receive food (APP: ~1.3 g loose food; APP+CONS: ~1.3 g encapsulated food). During the consummatory condition (CONS), they were provided with encapsulated food in a food trough. The drawing is not to scale (see text for correct dimensions).

APP+CONS), and by documenting the number of dispenser activations (APP and APP+CONS).

2.4. Statistical analysis

All analyses were done with IBM SPSS® Statistics (version 26.0 or higher).

2.4.1. Observer agreements

Between-observer agreements were calculated with five randomly selected test days from five different parrots in random test conditions using a two-way random, single measures, absolute agreement intraclass correlation (ICC; observers MB, AM, IdH). Within-observer agreements were calculated with four different semi-randomly selected test days from three different parrots in test condition APP+CONS using a two-way mixed, single measures, absolute agreement ICC for each observer. Values above 0.60 were considered to reflect moderate yet acceptable agreement, while values above 0.75 and above 0.90 represented good and excellent agreement, respectively (Hallgren, 2012; Koo and Li, 2016). The between-observer ICCs were all > 0.60. The within-observer ICCs were all > 0.90, with two exceptions ('eating' by AM and 'non-enrichment interactions' by IdH, both ICC>0.40) (see

Supplementary material S2).

2.4.2. Behavioural analyses

The time spent on the behavioural categories 'total daily foraging times', 'eating', 'non-enrichment interactions' and 'other' were analysed using a Repeated Measures (RM) ANOVA with test day and test condition (and their interaction if both parameters were significant) as within-subject factors (fixed) and sex a between-subject factor (random). The behavioural categories 'appetitive behaviour' and 'consummatory behaviour' were analysed using paired t-tests. Prior to the behavioural analyses, residual analyses were performed to check if assumptions for RM ANOVA and paired t-tests were met (QQ-plots, Shapiro-Wilk test, skewness and/or kurtosis). If this was not the case, a non-parametric model was chosen as alternative: related-samples Friedman's two-way ANOVA and Wilcoxon signed rank test, respectively. Significance was set at $p < 0.05$, and Bonferroni-corrected *post hoc* pairwise comparisons between test conditions were performed when a significant difference was found. Data are presented as mean±SD (if assumptions of normality were met), or as median, interquartile range (Q_1-Q_3) and minimum-maximum range (if assumptions of normality were not met). Furthermore, the critical value, (two-tailed) p-value and difference of means (DoM) are given for *post hoc* comparisons. A boxplot representing the

Table 1

Ethogram of observed behaviours (in minutes/24 h), which were all programmed as mutually exclusive state events in BORIS. Behaviours were pooled and analysed per category. The 'total daily foraging times' were calculated by adding eating, appetitive behaviour and consummatory behaviour.

	Category	Behaviours
Total daily foraging times	Eating	Feed from or search in food trough with beak
		Feed at or search on bottom of cage with beak (ground foraging)
	Appetitive behaviour	Hold marble with foot or beak
		Operate marble track (directly after inserting a marble, or when touching a lever with the beak)
		Wait for food or capsule after activating the dispenser (i.e., parrot sat idle)
	Consummatory behaviour	Manipulate capsule with foot and beak, picked up from dispenser or food trough
		Manipulate capsule with foot and beak, picked up from bottom of cage
Other	Non-enrichment interactions	Interaction with non-enrichment, manipulable items (wooden perch, newspaper, bowl, trough)
	Other	All other behaviours (e.g., preening, sleeping, vocalising)

total daily foraging times was created in SPSS and further refined in Adobe® Illustrator® (CC).

2.4.3. Food consumption and body mass

Food consumption was measured in gram/24 h (CTRL and APP), number of capsules opened per day (CONS and APP+CONS), and number of dispenser activations per day (APP and APP+CONS). A paired t-test was applied per variable to test for an effect between the conditions. To test if there was a change in daily food consumption over the 30-day periods, a linear regression coefficient was calculated per test condition for food consumption (gram/24 h), capsule consumption (#/24 h), and dispenser activations (#/24 h). Body mass (gram) was analysed with an RM ANOVA (if assumptions of normality were met) or related-samples Friedman's two-way ANOVA (if assumptions of normality were not met) for an effect of test condition. Bonferroni-corrected *post hoc* pairwise comparisons between test conditions were performed if a significant difference was found. Data are presented as mean±SD (if assumptions of normality were met), or as median, interquartile range (Q_1-Q_3) and minimum-maximum range (if assumptions of normality were not met). Furthermore, the critical value, (two-tailed) p-value and difference of means (DoM) are given for *post hoc* comparisons.

To test if there was a change in body mass over the 30-day periods, a linear regression coefficient was calculated per test condition. Linear regressions were only applied when these data met the assumptions of normality, homoscedasticity and absence of multicollinearity.

2.4.4. External factors

A possible confounding effect of the average daily room temperature was investigated by plotting data (i.e. scatterplots) and calculating linear regression coefficients per test condition. Linear regressions were only applied when these data met the assumptions of normality, homoscedasticity and absence of multicollinearity. R^2-values < 0.40 were considered to reflect weak correlation, while values > 0.40, > 0.70 and > 0.90 represented moderate, strong, and very strong correlations, respectively (Schober et al., 2018).

3. Results

Parrots learned to use the appetitive component (APP) in 63 ± 35 days (N = 10), and the consumptive component (CONS) in 6 ± 3 days (N = 12). Two parrots failed to learn how to independently use APP, and therefore could not complete the APP and APP+CONS test conditions.

As a result, these two parrots were excluded from further data analyses (i.e., N = 10).

3.1. External factors

The average daily room temperatures had a neglegible effect on total foraging times during all four test conditions (r < 0.1, $R^2 < 0.1$, N = 10).

3.2. Behavioural observations

3.2.1. Total daily foraging times

Overall, the parrots spent on average 121 ± 16 min/24 h on foraging during CTRL, compared to 176 ± 31, 194 ± 26 and 234 ± 42 min/24 h during APP, CONS, and APP+CONS, respectively. An RM ANOVA revealed a significant effect of test condition on total daily foraging times ($F_{(3;24)} = 46.970$, p < 0.001, N = 10), while test day did not significantly affect foraging times ($F_{(2;16)} = 0.239$, p $= 0.790$, N = 10) (Fig. 2) (see Supplementary material S3 for individual plots). *Post hoc* analysis revealed that parrots spent more time foraging in all three enrichment conditions compared to the control (APP: p < 0.001, DoM=55; CONS: p < 0.001, DoM=72; APP+CONS: p < 0.001, DoM=113). In addition, parrots were found to spend significantly more time on foraging during APP+CONS compared to both APP and CONS (APP: p $= 0.010$, DoM=58; CONS: p $= 0.027$, DoM=40), while no significant difference was found between APP and CONS (p $= 0.735$, DoM=18).

The sex of the parrot was a signifant between-subject factor ($F_{(1;8)} = 12.085$, p $= 0.008$, N = 10). Males spent on average 35 min/24 h longer on foraging than females. Further evaluation using an independent samples t-test revealed that this difference was only significant during APP, with males spending 49 min/24 h longer on foraging than females (see Supplementary material S4, Table S4.1).

3.2.2. Time spent on foraging-related and other activities

The median times spent on eating were 114, 116, 70 and 26 min/24 h for CTRL, APP, CONS and APP+CONS, respectively (Table 2). The
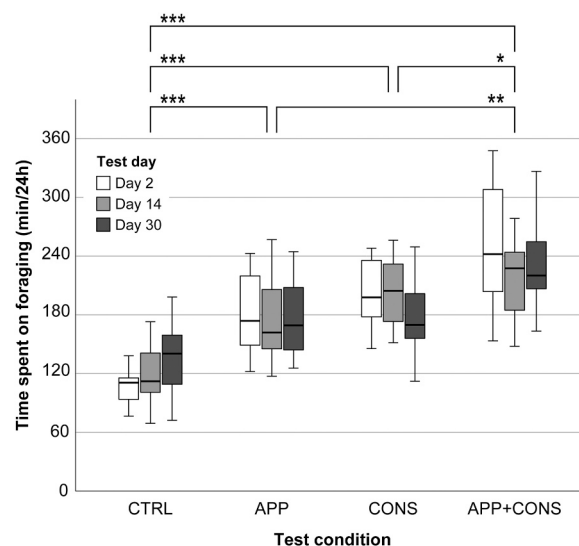

Fig. 2. Boxplot presentation of the time spent on foraging (min/24 h) by grey parrots (N = 10) at day 2, day 14 and day 30 in each of the four different test conditions (CTRL = control condition; APP = appetitive enrichment; CONS = consummatory enrichment; APP+CONS = appetitive and consummatory enrichment combined i.e., two-component enrichment). Data is visualised in boxplots with the median and interquartile ranges (Q_1-Q_3). Significant differences are marked with asterisks (*p < 0.05, **p ≤ 0.01, *** p ≤ 0.001; Bonferroni-corrected). There was no significant effect of test day on time spent on foraging.

Table 2

Median (Q1-Q3), minimum and maximum times spent on exploratory and foraging behaviours (min/24 h) by grey parrots (N = 10) in the four test conditions (CTRL = control; APP = appetitive enrichment; CONS = consummatory enrichment; APP+CONS = appetitive and consummatory enrichment combined). Asterisks (*), double daggers (‡), and daggers (†) represent significant differences compared to CTRL, APP+CONS, and between APP and CONS, respectively (two-tailed p < 0.05; Bonferroni-corrected).

	Test condition	Median (Q1-Q3)	Min	Max	Significance
Eating (min/24 h)	CTRL	114 (103–139)	69	173	$X^2_{(3,30)}$= 66.040
	APP	116 (100–151) ‡†	66	214	p < 0.001
	CONS	70 (43–83) *	17	119	
	APP+CONS	26 (2–50) *	0	150	
Appetitive behaviour (min/24 h)	APP	46 (39–60)	25	93	$t_{(29)}$= 0.401
	APP+CONS	48 (37–57)	29	70	p = 0.691
Consummatory behaviour (min/24 h)	CONS	132 (101–155) ‡	68	197	$t_{(29)}$= −3.929
	APP+CONS	154 (141–177)	78	216	p < 0.001
Non-enrichment interactions (min/24 h)	CTRL	12 (1–30)	0	114	$X^2_{(3,30)}$= 30.970
	APP	6 (0–18) †	0	47	p < 0.001
	CONS	0 (0–1) *	0	30	
	APP+CONS	0 (0–3) *	0	23	

time spent on eating differed significantly between test conditions ($X^2_{(3,30)}$= 66.040, p < 0.001, N = 10). *Post hoc* analysis revealed that parrots spent less time on eating during CONS and APP+CONS compared to CTRL (CTRL-CONS: p < 0.001; CTRL-APP+CONS: p < 0.001) and APP (APP-CONS: p < 0.001; APP-APP+CONS: p < 0.001). There was no significant difference between CONS and APP+CONS (p = 0.129) and APP and CTRL (p = 1.000).

The median time spent on appetitive behaviour during APP (46 min/24 h) did not differ significantly ($t_{(29)}$= 0.401, p = 0.691, N = 10) from that during APP+CONS (48 min/24 h; Table 2). However, median time spent on consummatory behaviour was significantly higher ($t_{(29)}$= −3.929, p < 0.001, N = 10) during APP+ CONS (154 min/24 h) compared to CONS (132 min/24 h; Table 2).

The median times spent on non-enrichment interactions were 12, 6, 0 and 0 min/24 h for CTRL, APP, CONS and APP+CONS, respectively (Table 2), and differed significantly between test conditions ($X^2_{(3,30)}$= 30.970, p < 0.001, N = 10). *Post hoc* comparisons showed that parrots spent less time on non-enrichment interactions during CONS (p < 0.001) and APP+CONS (p < 0.001) than during CTRL. Similarly, parrots spent less time on non-enrichment interactions during CONS compared to APP (p = 0.026), while interaction times did not differ between any of the other conditions (Table 2).

Males spent significantly more time on eating (U=0, Z = −2611, p = 0.008), and on non-enrichment interactions (U=1, Z = −2.402, p = 0.016) in APP than females. A similar trend, though not significant, could be observed for CTRL (U=4, Z = −1.776, p = 0.095). For other behavioural variables no significant difference between the sexes could be observed (see Supplementary material 4, Table S4.2).

3.3. Food consumption and body mass

A linear regression analysis showed no effect of test day on food consumption (r < 0.1, R^2 <0.1, N = 10). However, a Wilcoxon signed rank test did reveal a higher median consumption of food capsules in CONS compared to APP+CONS (CONS: 55 capsules, APP+CONS: 49 capsules; p = 0.005), as well as a tendency for a higher number of dispenser activations in APP+CONS compared to APP (APP: 42 activations, APP+CONS: 49 activations, p = 0.072; Table 3).

The median body mass of the parrots remained similar throughout the study period, with individual body mass ranging from 455 to 560 (Table 3). A linear regression analysis showed no effect of test day or test condition on body mass (r < 0.1, R^2 <0.1, N = 10). Males were heavier than females in all four test conditions (see Supplementary material 4, Table S4.3). Males also ate significantly more than females in APP (U=2, Z = −2.207, p = 0.032), and activated the dispenser more often than females in APP+CONS (U=0, Z = −2.643, p = 0.008), hence also consuming more capsules in APP+CONS than females (U=0, Z = −2.652, p = 0.008). For the other food consumption variables no differences between the sexes were identified (see Supplementary material 4, Table S4.3).

4. Discussion

The aim of this study was to evaluate whether foraging enrichment simulating both the appetitive and consummatory phases of foraging is helpful to approximate foraging times of wild conspecifics in grey parrots. Results demonstrate that the combined enrichment doubled foraging times from 2 to 4 h per day compared to the control. The separate components had an additive effect: each increased the daily foraging times with 1 h. We identified no effect of test day, suggesting

Table 3

Median (Q1-Q3), minimum and maximum food and capsule consumption, number of dispenser activations and body mass in grey parrots (N = 10) in the four test conditions (CTRL = control; APP = appetitive enrichment; CONS = consummatory enrichment; APP+CONS = appetitive and consummatory enrichment combined). Double daggers (‡) represent significant differences compared to APP+CONS (two-tailed p < 0.01; Bonferroni-corrected).

	Test condition	Median (Q1-Q3)	Min.	Max.	Significance
Food consumption (g/24 h)	CTRL	29 (27–35)	21	36	Z = 0.975
	APP	32 (29–34)	26	35	p = 0.328
Dispenser activations (#/24 h)	APP	42 (38–47)	29	56	Z = 1.797
	APP+CONS	49 (42–52)	32	53	p = 0.072
Capsule consumption (#/24 h)	CONS	55 (55–55) ‡	55	55	Z = −2.812
	APP+CONS	49 (43–52)	32	53	p = 0.005
Body mass (g)	CTRL	486 (467–524)	463	550	X^2 = 5.364
	APP	500 (473–527)	455	560	p = 0.147
	CONS	491 (461–530)	455	540	
	APP+CONS	491 (459–529)	449	548	

that neither habituation nor changes in motivation or use of the enrichment occurred during the 30-day observation period. Similarly, food consumption and body mass remained stable throughout the study, indicating that these could not serve as an explanation for the found differences.

The control condition resulted in average daily foraging times of 121 min/24 h, which is similar to the baseline times found by Lumeij and Hommers (2008) (116 min/24 h), but higher than baseline times in Rozek et al. (2010) (~42 min/24 h) and van Zeeland et al. (2013) (47 min/24 h). These differences in baseline foraging times could be explained by the type of food used and the way in which it was presented. In our study and the study by van Zeeland et al. (2013), Nutri-Berries were provided as food source, although the way of presentation differed (i.e. crushed, loose mixture versus whole Nutri-Berries, respectively). For these two studies, foraging times were relatively similar (i.e. 121 min/24 h versus 105 min/24 h). Other studies gave extruded pellets instead of seed mixtures, which might have resulted in overall lower baseline values, although no significant differences in foraging times were observed between extruded pellets and seed mixture in a study by Wolf et al. (2002). Additionally, in contrast to other studies, we provided food in a custom-made trough that was almost triple the size of a regular food trough (~125x380mm versus ~80x100mm). This led to food being dispersed over a bigger surface, which may have contributed to longer baseline foraging times due to prolonged searching for and selecting of food. Enrichment strategies that have similar effects are food scattering and mixing food with edible and inedible foraging substrates (e.g., Jacobsen et al., 2010; Smith and Gray, 2011; de Azevedo et al., 2013).

The appetitive and consummatory components separately yielded foraging times of approximately 180 min/24 h, which is substantially higher than the foraging times as found for the 11 foraging enrichment strategies tested by van Zeeland et al. (2013) (highest: 123 min/24 h). Two studies found similar daily foraging times to the single components in our study: Lumeij and Hommers (2008), who tested pipe feeders (160 min/24 h) as a means of enrichment; and Rozek et al. (2010), who provided oversized pellets (~185 min/24 h) to their parrots. Each of these enrichments stimulated repeated actions and podomandibulation as did our appetitive and consummatory components, which may explain the similarity in effectiveness of these enrichments.

Combining the appetitive and consummatory components provided an added effect, with foraging times (234 min/24 h, thus 4 h per day) being the highest thus far documented in a captive setting, based on the literature search we performed in Google Scholar. These foraging times are comparable to those of wild parrots (4–8 h/day; Gilardi and Munn, 1998; Symes and Perrin, 2003; Salinas-Melgoza and Renton, 2005; O'Hara et al., 2019). Despite reports of enrichment losing its effect over a longer period of time (Meehan and Mench, 2002; Rodríguez-López, 2016), we noted no decrease in foraging times throughout our 30-day observation period.

Through simulating appetitive behaviours such as exploring, searching and procuring food, the appetitive component of the enrichment intended to not only stimulate species-typical foraging behaviours, but also provide the added welfare benefit of a mental challenge. The actions that were required to activate the food dispenser were similar to activities as incorporated in commercially available foraging enrichment (e.g., open drawers, rotate surfaces, lift lids or pull levers; van Zeeland et al., 2013). Parrots are known for their advanced cognitive and problem-solving skills (Auersperg, Von Bayern, 2019), and some species have been shown to voluntarily perform object-object combination (Auersperg et al., 2014). Parrots can also be trained to perform object-object combination, as is evidenced by the many videos on the internet demonstrating parrots to, e.g., dunk a basketbal,[3] place a coin in

a piggy bank,[4] or ring toss.[5] In our study, we actively trained our parrots using target stick training, positive reinforcement and shaping to pick up a marble, and place and manoever it through the marble track. The time it took to complete the training varied greatly between parrots, from three weeks to four months. Multiple factors played a role, such as parrots' differences in motivation, learning ability, shyness towards trainer, or neophobia. Additionally, differences between trainers (e.g., experience, quality, consistency), training sessions (e.g., length, quantity, regularity), or external factors (e.g., distractions, technical failure) could have influenced the success of training, despite our efforts to standardize the training as much as possible. In the end, two out of 12 parrots failed to complete the training and independently use the appetitive enrichment, possibly due to their willingness to participate in the training being linked to social companionship of the trainer (Morales Picard et al., 2017).

The consummatory component provided a more fine-tuned physical challenge for parrots requiring them to use their beak, tongue, and foot (i.e., podomandibulate) to separate and extract the edibles from the inedible parts. All 12 parrots learned how to gain food from this component in a very short time (<12 days), likely because these behaviours (i.e., biting, tearing, opening, selecting, and extracting) are natural to them (Janzen, 1981; de Araújo and Marcondes-Machado, 2011; Mellor et al., 2021). Due to spillage of food on the floor (which is a natural habit of parrots; Sebastián-González et al., 2019), the consummatory component also provoked ground foraging, a behaviour also displayed by grey parrots display in the wild (May, 2001). As such, the enrichment enabled a diverse set of behaviours, which could positively affect the parrots' welfare.

In our study, we observed some of the parrots investigating the marbles that were part of the appetitive component. This could indicate that the marbles had an intrinsic reinforcing value for the parrots (e.g., novelty, sensory stimulation) that stimulated play and/or explorative behaviour (including podomandibulation). However, during analysis of the videos we did not distinguish goal-directed use of the marbles from other use such as object play or exploration. For future studies, further specifying the type of activities performed could help to identify the actual value and importance of specific enrichments and how these affects the parrots' welfare.

Upon comparing the test conditions, no noticeable differences were observed in the parrots' food intake for the appetitive enrichment compared to the food trough (control). We did observe a minor, though non-significant, difference between the appetitive and two-component enrichment in the number of dispenser activations, which could suggest a (slight) preference for the encapsulated food over free food, possibly due to (increased) stimulation of beak exercise and/or podomandibulation (as also suggested by Rozek et al., 2010; van Zeeland et al., 2013; Polley, 2015; James et al., 2021). Similarly, we observed a higher number of capsules being opened when providing these in the food through compared to providing them in the capsule dispenser. As this difference mainly comprised of the five empty capsules, this could mean that the parrots were only motivated to perform the appetitive task as long as food was involved. Alternatively, the empty capsules could have been harder to identify as these were randomly mixed in the food trough, and/or required less effort to open and destroy, hence serving as a viable option to further stimulate explorative behaviour and mimic natural foraging conditions that could benefit the bird's welfare.

In our study, we observed subtle sex differences in foraging behaviour, with males foraging longer than females, despite eating similar amounts. During breeding, male parrots usually feed their female partners (Fa and Cavalheiro, 1998; Gajdon et al., 2006; Heinsohn, 2008). Similarly, in many parrot species, the male is heavily involved in nest building activity (Eberhard, 1998; Spoon, 2006). These observations

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[3] https://www.youtube.com/watch?v=k7OX6CISFog

[4] https://www.youtube.com/watch?v=8vT1F99eovs

[5] https://www.youtube.com/shorts/dMhft8mGVpM

might explain why male parrots might have a higher motivation to forage or explore than females, resulting in longer foraging times and times spent on interaction with non-enrichment items, as found in our study. Hence, although not the primary focus of our study, sex differences should be taken into consideration when performing further studies into parrots' foraging needs.

5. Conclusion

The two-component enrichment increased foraging times to 4 h per day in our grey parrots, thereby approximating foraging times in wild parrots. Both the appetitive and consummatory component led to an extra hour on foraging per day compared to the control condition, with effects being additive upon combining the two components. As the combined enrichment stimulated a wide range of behaviours, behavioural diversity and complexity of the foraging task greatly increased, which could positively affect the birds' welfare. Whether and to what extent this is the case will be subject to future studies. Nevertheless, this study does emphasize the importance of considering both species-specific appetitive and consummatory activities when designing and implementing a foraging enrichment strategy for parrots; an approach that could possibly also be applied to other captive species.

CRediT authorship contribution statement

Beekmans: Conceptualization, Methodology, Investigation, Formal analysis, Visualization, Project administration, Funding acquisistion, Writing – original draft. **Vinke:** Supervision, Writing – review & editing. **Maijer:** Investigation. **de Haan:** Investigation. **Schoemaker:** Supervision, Writing – review & editing. **Rodenburg:** Writing – review & editing. **Kooistra:** Writing – review & editing. **van Zeeland:** Supervision, Conceptualization, Methodology Funding acquisistion, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.applanim.2023.105986.

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